The Impact of Ultra-Processed Food Consumption on Verbal Fluency and Learning: A Randomized Crossover Trial

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Dedication

Dedicated to my wife and children. *Soli Deo gloria*.

Acknowledgments

I am incredibly grateful to many people for their diverse contributions to this project. First, I am thankful to the 40 unnamed young people who served as participants in my study. Thank you for answering the call to research, taking the time to sit through the study protocol, and providing thoughtful answers to all four forms of the assessment. In a similar way, I am grateful to Haley Cocca, Corban Dyche, Manfred Eller, Fred Knarr, Mary Knarr, MaryAnn Russell, Rachel Stern, Galen Wiley, and Elsie Wiley who served as participants in my pilot study. Thank you for being available to help me at this important phase of my journey and providing feedback that helped me refine meal composition, portion sizes, and the online instrument. A special thanks to Galen Wiley, who also shared his office as a quiet working space that I used to write the bulk of my literature review and results section.

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Abstract

Ultra-processed food consumption is a globally increasing trend (Pagliai et al., 2021) correlated with increased obesity, cardiovascular disease, diabetes, and all-cause mortality (Elizabeth et al., 2020). American college students consume twice as many calories from ultra-processed food, compared to minimally processed food (Juul et al., 2022), and ultra-processed food has a suggested impact on academic performance as well (Blum et al., 2022; Martin, 2022). Verbal learning and fluency tests measure cognitive processes that are foundational for academic achievement (Thomas, 2022; Whiteside et al., 2016). Framed in Maslow's theory of needs (1943), the focus of this study was to answer the question: "What is the causal impact of processing level of food consumed (ultra-processed vs. minimally processed) and postprandial time (30 minutes vs. 90 minutes) on verbal fluency and learning?" A quantitative, laboratory-type controlled experiment was conducted with a 2x2 repeated-measures design. Two alternative breakfasts were designed to share essential ingredients and match total energy content but vary in processing level. Forty college students were randomized to receive each meal at the beginning or end of a one-week washout period. Two-way repeated-measures ANOVA revealed that verbal learning and phonemic fluency scores were highest at 30 minutes and 90 minutes, respectively. Regarding processing level, the ultra-processed meal improved phonemic fluency but not semantic fluency. However, the minimally processed meal improved four distinct measures of verbal learning. To enhance learning while simultaneously limiting chronic disease, it is recommended that institutions of learning and policymakers create environments that favor minimally processed food.

"Good nutrition creates health in all areas of our existence. All parts are interconnected."

(Campbell, 2005, p. 238)

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Chapter I. Statement of the Problem

Diet has an unequivocal impact on health and wellness. Poor nutrition has been identified as the single most important factor contributing to years of life lost or lived with disability (Afshin et al., 2019). On a global scale, the primary diet-related risks are the lack of fruits and whole grains and an excess of sodium (Afshin et al., 2019). These risks are especially problematic in minority communities (Maciel et al., 2022). Class- and race-mediated dietary differences can already be discerned within the first twelve months of life, appearing to impact a baby's growth in the first year of life (Wen et al., 2014).

Food type can be broadly conceptualized as various categories such as level of food processing. Unprocessed foods are unaltered, edible portions of whole foods; minimally processed foods have been preserved or modified in ways that do not impact their nutritional quality. Processed foods are those that have added salt, oil, sugar, or other isolated food components; ultra-processed foods have been extensively modified through methods only available at the industrial level such that little to no unprocessed food remains (Monteiro et al., 2017). Higher consumption of ultra-processed food has emerged as a globally increasing trend (Pagliai et al., 2021; Shim et al., 2021) that is correlated with increased obesity, cardiovascular disease, diabetes, and all-cause mortality (Elizabeth et al., 2020). Roughly 56% of calories in the U.S. come from ultra-processed food (Lane et al., 2021), and American college students consume twice as many calories from ultra-processed food, compared to minimally processed food (Juul et al., 2022). Diet has a clear impact on the overall quality of life of college students (Lanuza et al., 2022), and some authors have suggested that the removal of processed foods would result in higher academic performance as well (Blum et al., 2022; Martin, 2022).

The relationship between nutrition and academic outcomes is complicated, and the research in this area is incomplete. Medical literature has demonstrated the causal effects of

specific micro and macro-nutrients on various outcomes (Bellisle, 2004; Sorhaindo & Feinstein, 2006), but the discussion should expand from molecules to broader food types (Tapsell et al., 2016). Correlational and quasi-experimental studies have suggested a relationship between the consumption of processed food and decreased learning (Anderson et al., 2018; Belot & James, 2011; Doku et al., 2013; Hollar et al., 2010; Neumark-Sztainer et al., 1996; Peltzer & Pengpid, 2015). Consumption of processed food is correlated with lower overall cognition (Gonçalves et al., 2023; Melo et al., 2022; Ozawa et al., 2017) and verbal fluency (Akbaraly et al., 2009; Cardoso et al., 2022), but causal evidence in these relationships has not yet been fully explored.

Verbal learning, the ability to memorize new verbal information, is an indicator of learning ability (Spreen & Strauss, 1991) and is critical for academic success. Verbal learning tests are simple measures of basic memory gains over a short period of time. They are "ubiquitous" tools in the field of neuropsychology (Hawkins et al., 2004, p. 99). A causal connection between lower verbal learning and higher glycemic index, a food's ability to impact blood sugar, has already been demonstrated (Sanchez-Aquadero et al., 2020). Similarly, verbal fluency tests are a "mainstay" of neuropsychology (Cohen, 2020, p. 3) used to assess verbal ability and executive function in a variety of settings (Shao et al., 2014; Strauss et al., 2006). Therefore, the purpose of this quantitative inquiry was to attempt to directly determine the causal impact of processing level of food consumed on verbal learning and verbal fluency through a repeated-measures experimental design.

Problem Statement

Younger people are not immune from the impacts of poor diet. Food preferences are developed early in childhood (Elizabeth et al., 2020), and 88% of youth (age 14-18) and 83% of college students do not consume the recommended amounts of fruits and vegetables (Moore et al., 2017, Peltzer & Pengpid, 2015). These numbers do not improve with adulthood; 88% and

91% of adults do not consume the recommended numbers of fruits and vegetables, respectively (Lee-Kwan et al., 2017). This problem is exacerbated by a lack of basic access to healthy food options in many rural and urban locations. Food insecurity correlates with low academic performance, and 20% of low-income kindergarten children live in food deserts in the United States (Wang & Black, 2019).

The ability to commit verbal information to memory is a foundation of success in educational environments. Poor verbal learning is associated with reading difficulties in elementary students (Taha et al., 2022). On the other hand, higher verbal learning scores have a significant relationship with increased intelligence in 12–14-year-olds (Fard et al., 2016) and overall achievement levels in 12–16-year-olds (Thomas, 2022). Even at the college level, verbal learning predicts GPA in the first year of study (Imlach et al., 2017). Poor academic outcomes not only lead to frustration, sadness, anxiety, and other negative psychological feelings, but also social estrangement, delays in meeting life goals, and negative impacts on the broader workforce and economy (Islam et al., 2014).

Similarly, verbal fluency tests involve several processes that are critical for education, such as verbal ability and executive function (Shao et al., 2014, Whiteside et al., 2016). In a scholarly setting, verbal ability is needed to retrieve words from one's vocabulary, and executive function is needed to control thoughts for the purpose at hand (Shao et al., 2014). If a dietary factor is indeed causing deficits in verbal ability or executive function, it would be reasonable to suggest that learning and overall academic performance would suffer.

The relationship between nutrition and learning has been probed through various methodologies, but this research is incomplete. Correlational studies have indicated that better academic performance is associated with lower consumption of sodium (Na et al., 2022) and higher consumption of polyphenols from fruits and vegetables (Miranda et al., 2022; Peltzer &

Pengpid, 2015). Randomized controlled trials indicate a significant positive causal relationship between verbal learning and the Mediterranean diet (Valls-Pedret et al., 2015) and a class of polyphenols known as anthocyanins (Kent, Charlton, Netzel & Fanning, 2017; Kent, Charlton, Roodenrys, et al., 2017; Whyte & Williams, 2015). Narrowing the focus on consumption of processed food, quasi-experimental research by Anderson et al. (2018) hinted at a more causal link between consumption of processed food and decreased academic performance, but their conclusions are limited by the nature of the study. Consumption of processed food is correlated with decreased verbal fluency and other measures of executive function (Cardoso et al., 2022; Pilato et al., 2020; Weinstein et al., 2023). Despite negative correlations between consumption of processed food and various aspects of cognition (Gonçalves et al., 2023) evidence for a causal relationship between eating processed foods and verbal learning or fluency has not yet been demonstrated.

It is possible that ethical considerations have previously prevented more extensive experimental dietary manipulations that would test causation. However, recent work has suggested that even extremely modest changes in diet (i.e., one meal) allow a researcher to detect changes in cognitive variables using a repeated-measures experimental design (Sanchez-Aguadero et al., 2020). This same quantitative design can be applied to explore causation in additional aspects of nutrition that have yet to be tested empirically. To my knowledge, this study was the first empirical test of the effect of postprandial time and processing level of food consumed on verbal learning and fluency test scores in college students. Features of this study (i.e., strong experimental design, a focus on consumption of processed foods, college students as the target population, and objective measures of learning) have been repeatedly recommended in the literature on nutrition and learning (Berding et al., 2021; de Miranda et al., 2021; Kent, Charlton, Netzel & Fanning, 2017; Galioto & Spitznagel, 2016; Gauci, 2022; Gonçalves et al.,

2023; Martin, 2022; Marx et al., 2021; Mesas et al., 2022; Peltzer & Pengpid, 2015; Pilato et al., 2020; Sung et al., 2021; Weinstein et al., 2023).

Purpose of the Study

Therefore, the focus of this study was to investigate the unknown causal impact of processing level of food consumed and postprandial time on verbal learning and fluency. Terms like healthy and nutrition have historically been defined in many ways, but predominantly in terms of the presence or absence of specific micro- or macro-nutrients (Livingston et al., 2020). Instead of these micro- or macro-nutrients, nutrition in this study was investigated through a broader lens of food classification, ultra-processed vs. minimally processed foods (Monteiro et al., 2017). Regarding outcome variables, cognition is a more objective, less confounded, “purer measure” of academic potential than content-based test scores (Pilato et al., 2020, p. 2). Verbal learning and fluency were the specific outcome variables in this analysis.

Quantitative methods were appropriate for this investigation. Specifically, strong quantitative experimental designs are uniquely suited to investigate causation due to their ability to control for confounding factors (Johnson & Christensen, 2019, p. 35). In these methodologies, random assignment even allows control for variables that are currently unknown (Suter, 2012). By using a strong quantitative design, this study was able to provide evidence to support the causal impact of processing level of food consumed on verbal learning and fluency. Food processing level was defined according to Monteiro et al. (2017). Verbal learning was measured according to the Rey Auditory-Verbal Learning Test (Schmidt, 1996). Verbal fluency was measured through phonemic fluency and semantic fluency tests (Strauss et al., 2006). Postprandial time, the elapsed time after a meal begins, was also included in the analysis to increase sensitivity to changing physiological conditions. This study focused on college students in central Pennsylvania, ages 18-25 (Hochberg & Konner, 2020).

Research Questions and Hypotheses

The focus of this research was to answer the question: "What is the causal impact of processing level of food consumed (ultra-processed vs. minimally processed) and postprandial time (30 minutes vs. 90 minutes) on verbal fluency and learning?" In order to address this question, the study tested the following hypotheses:

$H1_{0:}$ There is no statistically significant relationship between processing level of food consumed and measures of verbal learning.

$H1_A$: There is a statistically significant relationship between processing level of food consumed and measures of verbal learning.

$H2_0$: There is no statistically significant relationship between postprandial time and measures of verbal learning.

$H2_A$: There is a statistically significant relationship between postprandial time and measures of verbal learning.

$H3_0$: Regarding measures of verbal learning, there are no statistically significant interactions between postprandial time and processing level of food consumed.

$H3_A$: Regarding measures of verbal learning, there are statistically significant interactions between postprandial time and processing level of food consumed.

$H4_{0:}$ There is no statistically significant relationship between processing level of food consumed and measures of phonemic fluency.

$H4_A$: There is a statistically significant relationship between processing level of food consumed and measures of phonemic fluency.

$H5_0$: There is no statistically significant relationship between postprandial time and measures of phonemic fluency.

$H5_A$: There is a statistically significant relationship between postprandial time and measures of phonemic fluency.

$H6_0$: Regarding phonemic fluency, there are no statistically significant interactions between postprandial time and processing level of food consumed.

$H6_A$: Regarding phonemic fluency, there are no statistically significant interactions between postprandial time and processing level of food consumed.

$H7_0$: There is no statistically significant relationship between processing level of food consumed and measures of semantic fluency.

$H7_A$: There is a statistically significant relationship between processing level of food consumed and measures of semantic fluency.

$H8_0$: There is no statistically significant relationship between postprandial time and measures of semantic fluency.

$H8_A$: There is a statistically significant relationship between postprandial time and measures of semantic fluency.

$H9_0$: Regarding semantic fluency, there are no statistically significant interactions between postprandial time and processing level of food consumed.

$H9_A$: Regarding semantic fluency, there are statistically significant interactions between postprandial time and processing level of food consumed.

Theoretical Framework

The overall interpretive framework for this study was postpositivism. This framework asserts the existence of external truth, such as causal relationships between various factors, which can be studied more-or-less objectively (Creswell & Poth, 2018). This approach was appropriate for a study on nutrition because it has been used often in the health sciences

(Creswell & Poth, 2018, pp. 23-24). As a scientific approach, postpositivism involves rigorous, systematic steps to gather and analyze data.

Thornton (1993) wrote that theory “allows seeing what we would otherwise miss; it helps us anticipate and make sense of events” (as cited in Merriam & Tisdell, 2016, p. 88). Whereas postpositivism is a foundational worldview, Maslow’s theory of needs is a specific theoretical lens that is compatible within this framework. Maslow (1943) suggested a hierarchy of five levels of needs: physiological, safety, love, esteem, and self-actualization. Learning has been identified with the apex of this hierarchy through phrases like “Maslow before Bloom” (Pokhrel & Chhetri, 2021, p. 138). Maslow’s theory was relevant for this work because it predicts that higher-level needs (e.g., learning) can only be fully satisfied once lower-level needs (e.g., nutrition) are met (Maslow, 1943). Maslow never explicitly analyzed the specific mechanisms by which food modulates academic outcomes, but Sorhaindo and Feinstein (2006, p. 6) developed a seven-component conceptual model implying that socioeconomic status and lifestyle factors affect child nutrition, which affects a triad of physical development, cognition, and behavior. These three factors are assumed to have a combined influence on school life outcomes. Maslow’s theory indirectly shaped the forming of the present study’s problem statement due to the assumption that learning requires basic needs to be fulfilled. Other researchers of the connections between nutrition and learning have incorporated this theory as well (Chinyoka, 2014; Griffin, 2015; Makero & Bii, 2018; Savas et al., 2017; Tshisikhawe, 2017).

Assumptions, Limitations, Delimitations

The claims of this study were restricted by several assumptions, limitations, and delimitations. First, it was assumed that food processing level will continue to be a relevant aspect of diet; this appears to be a sound assumption based on the global rise in processed food

consumption (Pagliai et al., 2021; Shim et al., 2021). Second, it was assumed that participants gave full effort in the tasks assigned. The final assumption was that the influence of external factors was minimized by the repeated-measures design. For example, it was assumed that a participant's ongoing dietary pattern or activity level did not reverse any effects of a manipulated meal. Experimental research is designed to spread the variation from these factors across treatment levels so that they cause no net confounding influence (Suter, 2012).

Regarding limitations, the experimental nature of the study required a choice of a specific set of foods, which may or may not have provided results that were representative of the food classifications in general. Unfortunately, it was unknown if alternative food choices would yield the same results or not, and it was impossible to test all possible food combinations through one study. Due to the controlled nature of an experimental design, any specific choice of food would have technically limited my ability to make claims about food classifications in general. Therefore, this limitation was unavoidable in an experimental study.

The selection of participants represents a delimitation. Because college students may represent a more affluent demographic, this limits transferability to the broader population (Peltzer & Pengpid, 2015). Even within a specific university's population of 18–25-year-old students, the selection of participants represents a delimitation. Random selection is the only way to fully ensure generalizability to the population of interest (Suter, 2012), but this is generally not possible in experimental research (Johnson & Christensen, 2019, p. 310). Although the conclusions of the study were technically limited to the population from which the sample was drawn, the targeted university population was intended to be representative of the broader college student population.

Significance of the Study

This study was noteworthy for several reasons. It addressed a gap in the literature regarding the causal link between processing level of food consumed and cognition, approaching the problem from the lens of food synergy. It also provided information that may influence policy, nutrition recommendations, and interventional programs to address food insecurity. The following sections address these ideas in detail.

Gap in Demonstrating Causation

Despite evidence suggesting a link between processing level of food consumed and learning, this proposed causation has never previously been demonstrated with a strong experimental research design. The scholarship in this area has long indicated a correlation between certain aspects of nutrition – i.e., consumption of fruits and vegetables – and improved academic performance (Doku et al., 2013; Neumark-Sztainer et al., 1996; Peltzer & Pengpid, 2015), but that connection was often weakened by the crude, self-reported measure of consumption and/or academic performance (Andrade et al., 2021; Pfreundschuh, 2022). Quasi-experimental studies have provided support for more less processed diets (Anderson et al., 2018; Belot & James 2011; Hollar et al., 2010), and phenomenological studies have investigated the perceived impact of negative food choices on learning (Walker, 2020). Food processing level was overlooked in traditional ways of studying nutrition (Juul et al., 2022), and a gap persists in the causal impact of processing level of food consumed on cognition (Gonçalves et al., 2023; Weinstein et al., 2023). Furthermore, the majority of research regarding diet and cognition focuses on older populations, so more studies are needed on young adults, specifically (Gauci, 2022).

Nutrient Reductionism vs. Food Synergy

The literature is not devoid of experimental studies of nutrition. Causation *has* been demonstrated with specific vitamins, minerals, and other nutrients (Sorhaindo & Feinstein, 2006), but this leads toward reductionistic discussions of individual biomolecules, instead of foods themselves. There seems to exist a tendency in the literature toward this nutrient reductionism, considering foods to be no more than the sum of their individual nutrient components (Messina et al., 2001). This assumption is evident in the description of Sorhaindo and Feinstein's (2006) seven-component conceptual model described earlier.

This reductionistic idea contrasts with the notion of whole foods as having the potential to interact with the body in new ways due to the synergy of the components naturally existent in the foods (Jacobs & Steffen, 2003). A top-down approach has been recommended of first identifying health-producing food patterns, then seemingly beneficial foods within those patterns, and then probing molecular components in search of mechanisms (Berding et al., 2021; Jacobs et al., 2011; Messina et al., 2001; Tapsell et al., 2016). This study was consistent with this latter approach by investigating a food classification, as opposed to individual molecules.

Policy and Recommendations

In general, a tension in the research exists about what constitutes healthful food. Some studies use indices to evaluate the nutritional quality of food, but these indices may be imprecise and include foods that are considered unhealthful elsewhere. For example, the United States Department of Agriculture [USDA] Healthy Eating Index, used by Anderson et al. (2018), provides positive scores for any meat products, with no recognition of the World Health Organization's classification of red meat and processed meat as carcinogens (International Agency for Research on Cancer, 2015). Inconsistencies like these may contribute to varying public perceptions of healthful vs. unhealthful food.

The aforementioned tendency towards nutrient reductionism adds to the confusion around nutritional guidelines. For example, studies or guidelines may condemn certain components –e.g., cholesterol – without naming the types of foods that contain those components (e.g., Bowen et al., 2018). Helping to define the distinction between healthful and unhealthful appears to be an important first step in resolving this confusion.

With stronger evidence of causation, policymakers now have the data-based support to make changes that would benefit the health and learning of children, youth, and adults worldwide. Furthermore, with the additional conceptual clarity that comes with discussing nutrition in terms of food types instead of food components, public health messaging itself may become more effective.

Interventions to Address Food Insecurity

Basic stable access to healthy food has been a formidable barrier for students living in poverty (Frndak, 2014; Wang & Black, 2019). Several authors have proposed policy and structural changes at the college level to increase the availability of affordable and healthy food (Anderson et al., 2022; Blum et al., 2022; Lanuza et al., 2022; Lunsford, 2022; Willis, 2021). School breakfast and lunch programs have been investigated as a partial solution for younger learners, but the effectiveness of these interventions on academic achievement has not consistently been demonstrated (Bellisle, 2004; Dykstra et al., 2016; Frisvold, 2015; Hollar et al., 2010; Schanzenbach & Zaki, 2014). This study provided evidence that can refine future interventional programs at the post-secondary level and encourage similar studies in younger populations as well.

Definition of Terms

Average cluster size — the total cluster size divided by the number of clusters in a verbal fluency test (Strauss et al., 2006)

Clustering — listing several examples within the same subcategory in a sequence during a semantic fluency test or words that start with the same two letters, words that differ only by a vowel sound, or are homonyms during a phonemic fluency test (Strauss et al., 2006)

Cluster size — the count of words in a given cluster, starting with the second word (Strauss et al., 2006)

Delayed recall — the number of list A words recalled during trial A.7 of the Rey Auditory-Verbal Learning Test (RAVLT), following a 20-minute delay (Spreen & Strauss, 1991, p. 155)

Food desert — a low-income census tract with at least a third of the population living a significant distance from the nearest supermarket (Frndak, 2014)

Group 1 minimally processed foods — "natural foods altered by processes that include removal of inedible or unwanted parts, and drying, crushing, grinding, fractioning, filtering, roasting, boiling, non-alcoholic fermentation, pasteurization, refrigeration, chilling, freezing, placing in containers, and vacuum-packaging" (Monteiro et al., 2017, p. 9)

Group 1 unprocessed foods — "edible parts of plants… or of animals… and also fungi, algae and water, after separation from nature" (Monteiro et al., 2017, p. 9)

Group 2 processed culinary ingredients — "substances derived from Group 1 foods or from nature by processes that include pressing, refining, grinding, milling, and drying" (Monteiro et al., 2017, p. 9)

Group 3 processed foods — "made essentially by adding salt, oil, sugar or other substances from Group 2 to Group 1 foods" (Monteiro et al., 2017, p. 9)

Group 4 ultra-processed foods — "formulations made mostly or entirely from substances derived from foods and additives, with little if any intact Group 1 food" (Monteiro et al., 2017, p. 9)

Immediate memory —the number of List A words recalled during trial A.1 of the RAVLT (Spreen & Strauss, 1991, p. 155)

Interference list (Distractor List, List B) — the list of 15 new words spoken by the examiner with a one-second interval between each word after the initial five learning trials of List A in the RAVLT (Spreen & Strauss, 1991, pp. 150-155)

Interference list score (List B score) — the number of List B words recalled during trial B.1 of the RAVLT (Hawkins et al., 2004, p. 102)

Interference trial (B.1) — the trial that follows the learning trials (A.1–A.5) to test recall of the new interference list (List B) of the RAVLT (Spreen & Strauss, 1991, pp. 151-152)

Intrusions — inclusion of incorrect words within a response set to a verbal fluency test (Balogh et al., 2023)

Learning trials (A.1–A.5) — the first five free-recall trials of the RAVLT (Hawkins et al., 2004, p. 100)

Perseverations — repetitions within a response set to a verbal fluency test (Balogh et al., 2023)

Phonemic fluency (letter fluency) — a verbal fluency outcome based on a specific starting letter, such as F (Strauss et al., 2006)

Postdistractor trial (A.6) — the trial testing recall of list A, following the interference trial of list B (Spreen & Strauss, 1991, p. 151)

Postprandial time — the amount of time after meal consumption begins (Sanchez-Aguadero et al., 2020).

Proactive interference — the decremental effect of learning list A on learning list B, calculated as B.1 – A.1 (Spreen & Strauss, 1991, p. 151)

Processing — "physical, biological and chemical processes used after foods are separated from nature, and before being consumed or prepared as dishes and meals" (Monteiro et al., 2017, p. 9).

Recognition test — the final assessment of the RAVLT, in which participants identify List A words from a set of 50 words including List A, List B, and 20 semantically and/or phonemically similar words (Spreen & Strauss, 1991, pp. 150-151)

Repeated-measures design — an experimental design in which all participants experience all conditions of an experiment (Johnson & Christensen, 2019, p. 331)

Retention (intermediate memory; post-interference list A recall score) —the number of list A words recalled during trial A.6 of the RAVLT, following the interference trial (Denhart, 2018, p. 7, Hawkins et al., 2004, p. 102; Spreen & Strauss, 1991, p. 154)

Retroactive interference — "the decremental effect of subsequent learning on the retention of previously learned material," measured by the percentage of words lost from trial A.5 to A.6 (Spreen & Strauss, 1991, p. 151)

Rey Auditory-Verbal Learning Test (RAVLT) — a brief instrument that measures verbal learning, consisting of five learning trials (A.1–A.5) preceded by the reading of a stimulus list (List A), one trial (B.1) preceded by interference list (List B), one trial (A.6) to measure retention of list A, one trial to measure delayed recall of list A (A.7), and a test of recognition of list A (Spreen & Strauss, 1991, pp. 150-155)

Semantic fluency (category fluency) — a verbal fluency outcome based on a specific category, such as animals (Strauss et al., 2006)

Stimulus list (List A) — the initial list of 15 words spoken by the examiner with a one-second interval between each word during trials A.1–A.5 in the RAVLT (Spreen & Strauss, 1991; Denhart, 2018, p. 7)

Switching — transitioning from one cluster to a new cluster in a verbal fluency test (Strauss et al., 2006)

Total cluster size — the sum of all cluster sizes in a verbal fluency test (Strauss et al., 2006)

Total recall score — the sum of List A words recalled in trials A.1–A.5 in the RAVLT (Spreen & Strauss, 1991, p. 151; Hawkins et al., 2004, p. 100)

Verbal fluency — the outcome of a short neuropsychological test in which participants produce as many words as possible in a given amount of time that fit given criteria, without duplication (Strauss et al., 2006)

Verbal learning — the ability to freely recall words from a predetermined list, according to the procedure used in the Rey Auditory-Verbal Learning Test (Schmidt, 1996)

Chapter Summary

Food access and choices have ramifications for health and learning. Policymakers and individual consumers would benefit from investigations of the causal impact of food processing on cognition. A strong experimental design is necessary to make such claims, but this form of evidence was previously lacking. The present study not only provided evidence for such a connection but also provided a discussion of how such evidence may fill additional gaps in the literature. The literature review that follows will discuss the general and specific theoretical lens involved in this study, an overview of the concepts involved, a description of the current nutritional context, and connections between concepts currently demonstrated in the literature.

Chapter II. Review of the Literature

The following literature review begins with a discussion of the theoretical underpinnings of the study, including postpositivism and Maslow's theory of needs. This theory is briefly explained and then applied to nutrition, learning, and the connection between nutrition and learning. Criticisms and suggestions for revision are also considered. The last component of the theoretical section of the review is a justification for replacing nutrient reductionism with a synergistic view at higher levels of organization.

The second overall section of the review is a discussion of concepts related to the research variables. This section begins with introductions to relevant food components and dietary patterns, followed by an explanation of the dietary guidelines for Americans. Food processing and the Nova system are described in terms of their benefits and drawbacks. Cognition is introduced, followed by a detailed explanation of verbal learning and fluency.

The third overall section is a review of the context for this study. The current status of diet quality and food processing is reviewed, along with demographic patterns in consumption of processed food and reasons behind trends. Diet quality and barriers to healthy eating, especially food insecurity, are specifically examined in the targeted group of this study, college students.

The final overall section of the review highlights relevant connections between various nutritional levels (i.e., food components, specific foods, dietary patterns, and degree of food processing) and various outcomes (i.e., physical health, mental health, academic performance, and cognition). This section ends with an examination of the proposed mechanisms behind these connections.

Theory

According to Thornton (1993, p. 88), theory "allows seeing what we would otherwise miss; it helps us anticipate and make sense of events." The underlying approach to this work is

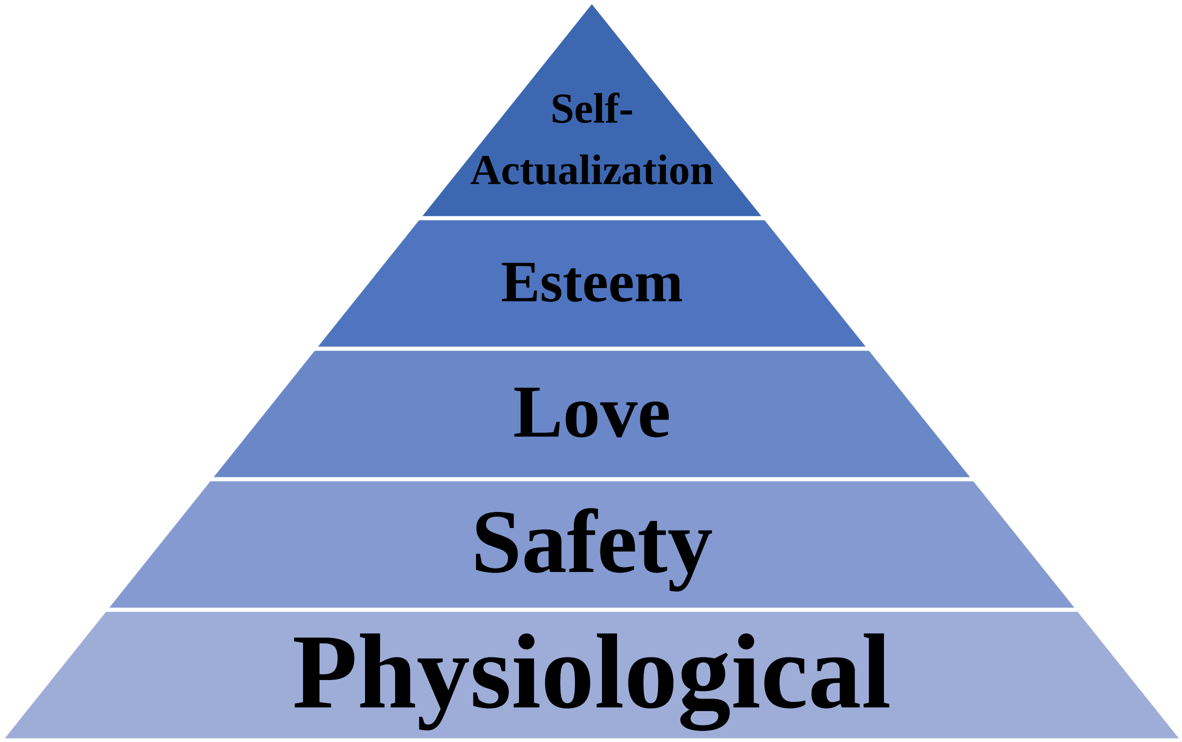
post-positivism. Post-positivism assumes that objective reality can be studied and discerned, even if methods to study that reality have the potential to be biased. Post-positivism is appropriate for this study due to its compatibility with a strong experimental design, and it has been frequently used in health sciences (Cresswell, 2018). Discussion of causal relationships, such as the potential causal relationship between eating processed foods and verbal learning, assumes this approach. Within the overall framework of post-positivism, Maslow's theory of needs is the specific theory that informed the interpretation of this study.

Maslow's Theory of Needs

Introduction of the Theory of Needs. As shown in Figure 1, Maslow's theory described a hierarchy of five levels of needs: physiological, safety, love, esteem, and self-actualization. Maslow (1943) identified the biological needs for food, water, and sex as physiological needs, but indicated that generating a comprehensive list of physiological needs seemed "impossible and useless," (p. 372). He connected physiological needs with the biological process of homeostasis, indicating that a long list of vitamins, minerals, and other nutrients need to be kept in balance by the body. More recently, Taormina and Gao (2013) operationally defined physiological needs as "the lack of chemicals, nutrients, or internal (e.g., exercise/health) or environmental (e.g., temperatures) conditions necessary for the body to survive, such that the extended absence of these things could lead to psychological stress or physical death" (p. 157).

Figure 1

Maslow's Theory of Needs



Note. Change in font size is intended to emphasize the concept of relative prepotency (Maslow, 1943, p. 375)

Similarly, Maslow (1943) did not define the rest of the needs by an exhaustive list. However, threats, pain, loud noises, flashing lights, injustice, and lack of consistent routine were all mentioned as potential triggers related to safety. Love needs were associated with affection, belonging, friendship, romantic relationships, and parenthood. Esteem needs were defined as "a stable, firmly based, (usually) high evaluation of themselves, for self-respect, or self-esteem, and for the esteem of others" (Maslow, 1943, p. 10). This need was described as a sense of demonstrated competence, appreciation, achievement, self-confidence, and worth. Finally, Maslow (1943) described self-actualization as fulfilling one's purpose or calling, so that a person is "doing what he is fitted for" (p. 11).

These needs are arranged such that the lower-level needs set a pre-requisite foundation for the higher-level needs. Maslow (1943) stated,

> The less prepotent needs are… minimized, even forgotten or denied. But when a need is fairly well-satisfied, the next prepotent ('higher') need emerges, in turn to dominate the conscious life and to serve as the center of organization of behavior, since gratified needs are not active motivators. (p. 18)

Thus, one would predict that needs function like the rungs of a ladder that must be climbed sequentially. Just as a climber may fall off a ladder and restart at the first rung, present circumstances may suddenly drop motivation back to meeting physiological needs.

Application to Current Study. Maslow's theory has been previously applied to the areas of nutrition and learning (Chinyoka, 2014; Griffin, 2015; Makero & Bii, 2018; Savas et al., 2017; Tshisikhawe, 2017). Maslow (1943) explicitly listed nutritional needs as a prime example of the physiological level of the hierarchy, so food is more foundational to Maslow than safety or shelter (Cassar, 2022). Feeling hungry at school is common for low-income learners (Cassar, 2022). This may seem inconsequential, but Maslow (1943, p. 387) wrote that "People who have never experienced chronic hunger are apt to underestimate its effects and to look upon food as a rather unimportant thing." It is very difficult for anyone, especially young people, to move beyond the basic need of food (Martin, 2022).

Maslow's theory does not just apply to the presence or absence of food in general, but the quality of food itself. Subjective feelings of hunger may indicate at least three distinct types of physiological needs: food insecurity resulting in an overall lack of calories, malnutrition resulting from a nutrient-poor diet, or even temporary blood sugar fluctuations caused by a single meal of low nutritional quality (Cassar, 2022). Martin (2022, p. 99) observed that "although Maslow's hierarchy of needs states that a person must satisfy the immediate physiological

needs… he never states the quality of ways the person meets his or her needs." Maslow (1943) acknowledged his ignorance of the vast number of specific nutrients that must be kept in homeostasis and was not interested in naming them all. Nevertheless, Taormina and Gao (2013) emphasized the potential for serious consequences if the body fails to keep all of those nutrients in balance.

Specifically, Maslow’s theory provides a unique lens for viewing processing level of food consumed. Those who are in a higher level of Maslow’s hierarchy tend to consume healthier foods (van Lenthe et al., 2015), whereas those in low-income households who tend to struggle to meet basic needs purchase more ultra-processed foods (Coyle et al., 2022). Despite Martin’s (2022) assertion that healthful foods are more appealing to students, ultra-processed foods have been demonstrated to induce higher approach motivation than unprocessed foods (Lemos, 2022). These foods are designed to be appealing through calorie-dense ingredients, additives, and aggressive marketing. The sensory properties of these foods “may make it very difficult to resist the overwhelming temptation to consume them, a factor exacerbated by aggressive marketing campaigns" (Lemos, 2022, p. 10). Nevertheless, there seems to be a potential disconnect between the sensory appeal of these foods and their ability to satisfy physiological needs. In an interventional study, high school learners indicated that traditional, processed school lunches left them feeling unsatisfied, but fresh food left them feeling full and nourished (Cassar, 2022).

Although Maslow (1943) did not specifically identify learning with a certain level of the hierarchy, it seems to reside at a high level, if not the highest. Indeed, Pokhrel and Chhetri (2021) referenced the modern educational adage that a learner must “Maslow before Bloom” (p. 138). This adage implies that effective instructional design is only effective if learners have well-met needs and are ready to learn. Cassar (2022) more explicitly stated that learning occurs at the

self-actualization level. Indeed, it would be difficult to argue that learning is not an integral part of fulfilling one's vocational calling.

Finally, Maslow's theory can also provide a lens for viewing the connection between nutrition with academic outcomes. Filippello et al. (2019) indicated that the risk of student absenteeism is greater when lower-level needs are not met, and Crandall et al. (2019) indicated a similar phenomenon with depression. Cassar's (2022) participants perceived that fresher, healthier food made them more engaged in class, leading to a bold statement that "Students could not learn effectively while malnourished" (p. 22). The literature is filled with potential mechanisms that may connect physiological needs and learning (Berding et al., 2021; Foster et al., 2013; International Agency for Research on Cancer [IARC], 2021; Leo & Campos, 2020; Marx et al., 2021; Mesas et al., 2022; Noble et al., 2017; Pagliai et al., 2021; Więckowska-Gacek et al., 2021; Zinöcker & Lindseth et al., 2018). Maslow (1943) never delved into these mechanisms; his framework focused on the overall priority that each need was given in the brain.

Critique. Since its original publication, Maslow's theory has faced criticism and suggestions for revision. Martin (2022) criticized the hypothesis that higher-level needs can only be met once lower-level needs are fulfilled, observing that students can delay gratification of lower-level needs. A strict interpretation of Maslow's theory would imply that those with unmet physiological and safety needs would not seek higher-level needs, such as romantic relationships. However, each learner living in poverty who chooses to date provides counterevidence to this hypothesis (Kenrick et al., 2010). According to Hale et al. (2019)

> The deprivation of a need is often overarching to other feelings and needs within a person, but it does not prevent the person from realizing and fulfilling higher needs… modern-day theorists have amended this conceptualization of the needs to coexist with

> one another, stating that humans still possess higher order needs even if their rudimentary ones are not met. (p. 109)

Therefore, Kenrick et al. (2010, p. 293) argued that humans utilize “multiple and independent fundamental motivational systems” with tiers that can be intermingled, overlapped, and interconnected. The authors also integrated biological context into their revision by replacing self-actualization with parenting (Kenrick et al., 2010). Although the latter revision is not universally accepted, the idea that nutrition and learning needs overlap can help inform the results of this study.

Nutrient Reductionism vs. Food Synergy

For decades, much of the research on nutrition and learning focused on individual nutrients, as opposed to foods or dietary patterns (Sorhaindo & Feinstein, 2006). While this research is useful to help elucidate specific mechanisms, it has limited ecological validity and relevance for consumers making decisions on what foods to eat. Lunsford (2022, p. 15) quipped that “people eat food, not nutrients.” Messina et al. (2001) described the tendency to study individual components as nutrient reductionism, considering foods to be no more than the sum of their individual parts. However, food is a complex matrix with nutrients that may interact in synergistic ways (Aguilera, 2019; Bernice, 2021). Therefore, Messina et al. (2001) called for a new approach of food synergy, a sentiment echoed by others in the field (Berding et al., 2021; Bernice, 2021; Kent, Charlton, Netzel & Fanning, 2017; Jacobs & Steffen, 2003; Tapsell et al., 2016).

A brief overview of phytochemicals can reveal why nutrient reductionism is an inadequate approach. Phytochemicals are plant-based molecules that do not fit into the categories of carbohydrate, lipid, protein, or nucleic acid, yet they have increased biological activity when consumed in combination with other phytochemicals (Lila et al., 2004; Liu, 2003; Margină et al.,

2020; Philip et al., 2019). About 5,000 phytochemicals have been identified, but it is estimated that whole foods contain a complex mixture of approximately 8,000 phytochemicals, on average, which affect each other in synergistic ways (Berding, 2021; Liu, 2003). Other components, such as poly-unsaturated fatty acids also exhibit these synergistic effects (Margină et al., 2020), particularly when consumed as whole foods (Lila et al., 2004). Focusing on one food component can lead to contradictions (Pistollato & Battino, 2014), so Margină et al., (2020) emphasized the importance of considering the combined impact of several molecules, especially in small daily doses. Therefore, the discussion of nutritional impacts on other variables should expand from molecules to whole foods (Kent, Charlton, Netzel & Fanning, 2017) and broader food types (Tapsell et al., 2016).

Moving from the nutrient level to the food level may not be enough. Even a research shift from micronutrients to whole foods may miss the synergistic effects on health and the microbiome that results from combining food groups together (Berding et al., 2021; Cardoso et al., 2022; Jacobs et al., 2011; Theobald, 2004). Foods are not consumed in isolation, but rather as a broader dietary pattern, defined as “the combination of foods and beverages that constitutes an individual’s complete dietary intake over time” (USDA & U.S. Department of Health and Human Services [HHS], 2020). The Mediterranean diet has emerged as one such dietary pattern with the potential to impact learning outcomes (Bernice, 2021; Livingston et al., 2020). Berding et al. (2021), wrote

> The fact that many different dietary patterns have been linked to improved mental wellbeing reinforces the fact that individual components of the diet may be less important to mental health than overall dietary patterns high in plant foods and low in ultra-processed foods. (p. 1270)

Nutrition research and policy have shifted dramatically within the last 20 years. Messina et al. (2001) were some of the first writers to recommend a focus on whole dietary patterns, but this shift has only been fully evident in the literature since 2015 (Livingston et al., 2020). Meanwhile, perceptions of food healthfulness continued to be based on individual nutrient levels. As of 2018, nutritional guidelines still tended to focus on individual components instead of the types of foods that contain those nutrients (Bowen et al., 2018). The current U.S. dietary guidelines for Americans continue to discuss salt, sugar, saturated fat, and other components at length, but also have a focus on dietary patterns, explicitly discussing synergistic impacts on health. A stated goal of the latest version of the dietary guidelines is an emphasis on “the importance of a healthy dietary pattern as a whole— rather than on individual nutrients, foods, or food groups in isolation" (USDA & HHS, 2020, p. viii). Researchers are now investigating broader food types and patterns. Nevertheless, the National School Lunch Program has been criticized for still focusing on individual nutrients and calories, as opposed to broader classifications, freshness, and satiation (Cassar, 2022).

For these reasons, the present study includes a discussion of all levels of nutritional precision (molecules, foods, dietary patterns, and broad food types). However, in keeping with the recent trend in literature that eschews nutrient reductionism and acknowledges food synergy, the research design itself focuses on overall processing level as an example of a higher level of food classification.

Concepts Related to Research Variables

Food Components

Nutritional research has historically focused on individual nutrients (Sorhaindo & Feinstein, 2006). Whereas the present study is intended to analyze nutritional classification at a higher level, discussion at the nutrient level is warranted due to the continued relevance of

nutrients on dietary guidelines. The dietary guidelines for Americans limit three nutritional components (sugar, sodium, and saturated fat) as part of the definition of nutrient-dense foods (USDA & HHS, 2020). Those three components, as well as fiber, are also involved in the Nutri-Score system of nutritional quality assessment (IARC, 2021). Fiber is viewed as a beneficial nutrient due to its ability to contribute to feelings of satiety and limit overeating (Zhang et al., 2021).

One class of food components of interest is the group of additives, flavorings, and incidental byproducts of industrial food processing. In processed food, flavorings are engineered to provide artificially intense taste responses that can lead to overeating (Pagliai et al., 2021; Zhang et al., 2021). Several other components are the products of industrial food processing that raise concerns due to their impacts on health. Advanced glycation end products are created through the processing of meat and fat (Uribarri et al., 2010). Acrylamide is produced by heating food in general, and acrolein is produced by heating fat, specifically (Pagliai et al., 2021 Zhang et al., 2018). Phthalates, bisphenol A and bisphenol S, found in plastic packaging, can leach into pre-packaged food (Pagliai et al., 2021; Rancière, 2015; Serrano et al., 2014).

Phytochemicals are small, biologically active components in plants (Liu, 2003). Fruits, vegetables, whole grains, nuts, spices, cocoa, extra virgin olive oil, coffee, green tea, and red wine are particularly rich in polyphenols, which are a type of phytochemical (Berding et al., 2021). Polyphenols include both flavonoids and nonflavonoids such as lignans, tannins, and stilbenes (Berding et al., 2021). Flavonoids, specifically, have been well-studied due to their potential for protecting brain health; they are found in high concentrations in cocoa, tea, wine, and fruits and vegetables (Kent, Charlton, Roodenrys, et al., 2017). Flavonoids include sub-categories such as anthocyanins, flavanols, flavonols, flavanones, and isoflavones (Berding et al., 2021; Kent, Charlton, Roodenrys, et al., 2017). Berries are especially high in flavonoids (Pérez-

Jiménez et al., 2010), leading to a strong focus on their potential impacts in the literature on nutrition (Kent, Charlton, Roodenrys, et al., 2017).

Dietary Patterns

The Western-style diet is low in plant foods and their associated fiber, polyphenols, vitamins, and minerals and high in sugar, sodium, saturated fat, trans fat, soft drinks, red meat, and fried and processed food (Berding et al., 2021; Drake et al., 2018; Jacka et al., 2010; Krivanek et al., 2021; Marx et al., 2021; Melo et al., 2022; Nyaradi et al., 2014). Despite perceptions that this diet is "normal" or "very healthy" (Fondevila-Gascón et al., 2022, p. 13), the Western diet is linked to negative outcomes in physical health, mental health, and cognition (Marx et al., 2021; Melo et al., 2022; Więckowska-Gacek et al., 2021).

In recent years, several dietary patterns have emerged as alternatives to the typical Western-style diet. In contrast to the Western-style diet, the prudent style diet includes less sugar, alcohol, red and processed meat, saturated and trans-fats, and refined grains (Shakersain et al., 2016). In addition, the Mediterranean, Dietary Approach to Stop Hypertension (DASH), and Mediterranean-DASH Intervention for Neurodegenerative Delay (MIND) diets have been studied due to their supposed cardiometabolic and brain health benefits (Krivanek et al., 2021). The Mediterranean diet is characterized by high consumption of fiber from antioxidant-rich whole fruits, vegetables, legumes, nuts, cereals, fish, and olive oil and low consumption of salt, meat, and saturated fat (Krivanek et al., 2021; Livingston et al., 2020). The similar DASH diet is intended to lower sodium and fat; unlike the Mediterranean diet, it includes low-fat dairy foods, but not red wine (Krivanek et al., 2021). The MIND diet emphasizes berries and green leafy vegetables (Krivanek et al., 2021). All of these diets are rich in anthocyanins and other polyphenols (Bernice, 2021).

Food Processing

The extent of food processing was overlooked in traditional ways of studying nutrition (Juul et al., 2022). Processed foods can be thought of as packaged, convenient, pre-prepared foods with many ingredients (The Nutrition Source, 2021). These foods can be eaten in-home or away from home but tend to be consumed in higher proportions away from home (Wang et al., 2021). A broad definition of food processing is “physical, biological and chemical processes used after foods are separated from nature, and before being consumed or prepared as dishes and meals” (Monteiro et al., 2017, p. 9). The USDA Agricultural Marketing Service (2022, p. 2) defines processed food as “a covered commodity [food requiring country of origin labeling] that has undergone specific processing resulting in a change in the character of the covered commodity, or that has been combined with at least one other covered commodity or other substantive food component.” Examples of these processes include baking, boiling, broiling, curing, drying, emulsifying, extruding, frying, grilling, roasting, smoking, and steaming (USDA Agricultural Marketing Service, 2022). Sugar, salt, oil, artificial colors, flavors, preservatives, or other additives are frequently added to these foods for taste, texture, preservation, appeal, or other reasons (Elizabeth et al., 2020; Monteiro et al., 2017; Monteiro, Cannon, Levy, et al., 2019; The Nutrition Source, 2021).

Nova System. There are four major methods of classifying foods according to their degree of processing, but the most commonly used approach is the Nova system (Martinez-Perez et al., 2021). The Nova system is widely used in policy and research (Monteiro et al., 2016). It classifies foods based on the “extent and purpose of industrial processing" (Monteiro, Cannon, Levy, et al., 2019, p. 936). The Nova system (Monteiro et al., 2010) is recognized by the Pan American Health Organization [PAHO], the Food and Agriculture Organization of the United Nations [FAO], and the World Health Organization [WHO] as the preferred way to classify food

according to their level of processing (Monteiro, Cannon, Lawrence, et al., 2019; PAHO, 2015; The Nutrition Source, 2021).

The Nova system classifies food items into four groups: unprocessed and minimally processed foods, processed culinary ingredients, processed foods, and ultra-processed foods (Monteiro et al., 2017). Group 1 includes both unprocessed and minimally processed foods. Unprocessed foods are edible parts of algae, animals, fungi, and plants that have been unaltered other than separating them from nature. An example of this type of food would be an apple. Minimally processed foods include the previously mentioned foods that have been altered in ways that affect their nutritional composition in minor ways, if at all. Such processes include boiling, chilling, crushing, drying, grinding, filtering, fractioning, freezing, non-alcoholic fermentation, packaging, pasteurization, refrigeration, roasting, and separating out unwanted parts. Frozen berries would be an example of minimally processed foods. Group 2 includes processed culinary ingredients. These ingredients are derived from the natural world by drying, grinding, milling, pressing, and refining. Sugar, salt, and oil are three common processed culinary ingredients. Group 3 includes processed foods that are produced by adding Group 2 substances to Group 1 foods. For example, sweetened applesauce, consisting only of fruit and sugar, would be a processed food. Group 4 includes ultra-processed foods. These are combinations of processed culinary ingredients and additives with little to no minimally processed food included. For example, packaged potato chips or bagged sweet snacks are ultra-processed foods (Monteiro et al., 2017). These foods are made with ingredients and processes that are only available at the industrial level (Andrade et al., 2021; Monteiro et al., 2010). Monteiro, Cannon, Levy, et al., (2019) state that one practical method for identifying ultra-processed food is to look for an ingredient that is rarely used in home kitchens.

There is debate about the overall appropriateness of the Nova system (Marino et al., 2021). First, it has been criticized for being too imprecise (Gibney, 2019; Jones, 2019). The general nature of the four categories can cause confusion, and there is no exhaustive, definitive list of which foods fit into which categories (The Nutrition Source, 2021). Furthermore, Nova's focus on food processing methods, as opposed to nutrient composition, has also been criticized. For example, Gibney et al. (2017) argued that ultra-processed food does not always have a substandard nutritional profile. Some processed Group 2-4 foods fit within current dietary guidelines for Americans (Marino et al., 2021). Plant-based oils high in unsaturated fatty acids are one such example (USDA & HHS, 2020).

Nutritional Quality. Some have argued for the benefits of processed food (Weaver et al., 2014). Food processing provides clear benefits in terms of low-cost, high-profit, tasty foods with a long shelf life (Baker et al., 2020; Weinstein et al., 2023). Industrial processing methods have become increasingly productive and efficient, permitting the transport of large quantities of food over long distances (Baker et al., 2020). Fortified processed foods increase the intake of certain vitamins and minerals. Furthermore, preservation methods reduce the risk of microbial infection or spoiling (Martinez-Perez et al., 2021).

Despite its clear benefits, ultra-processed food is associated with poor overall diet quality (Juul et al., 2019; Martínez Steele et al., 2017; Monteiro, Cannon, et al., 2018; Monteiro, Cannon, Lawrence, et al., 2019). Food processing generally has an adverse impact on the bioactive components of food (Shahidi, 2009). Many beneficial components are reduced in these foods, such as fiber (Andrade et al., 2021; Capra, 2022; Hall et al., 2019; Moubarac et al., 2017; Wang et al., 2021), omega-3 fatty acid (Hall et al., 2019), and protein (Capra, 2022; Moubarac et al., 2017). Phytochemicals and polyphenols are found in greater concentrations in skins and hulls that are often removed in food processing (Shahidi, 2009). As a result, food processing

negatively affects polyphenol content (Kent, Charlton, Netzel & Fanning, 2017; Rothwell et al., 2013). For example, heating reduces anthocyanin content by over 70% in blood plum jam-making (Fanning et al., 2014).

At the same time, food processing increases the concentrations of several problematic components. For example, processed food and drinks tend to have elevated sugar content (Andrade et al., 2021; Capra, 2022; Gibney, 2019; Hall et al., 2019; Martinez-Pere et al., 2021; Monteiro, Cannon, Lawrence, et al., 2019; Moubarac et al., 2017; Wang et al., 2021). It is estimated that ultra-processed foods account for 65–90% of calories obtained by added sugar on a national scale (Martínez Steele et al., 2016; Rauber et al., 2019). In addition to elevated sugar, higher total carbohydrates (Andrade et al., 2021; Moubarac et al., 2017; Wang et al., 2021) and refined grains (Capra, 2022) may contribute to the higher glycemic index of processed food (Martinez-Perez et al., 2021). Higher carbohydrates, total fat (Andrade et al., 2021; Gibney, 2019; Martinez-Perez et al., 2021; Moubarac et al., 2017), and saturated fat (Andrade et al., 2021; Hall et al., 2019; Martinez-Perez et al., 2021; Monteiro, Cannon, Lawrence, et al., 2019; Moubarac et al., 2017) may explain the overall higher energy density of processed food (Andrade et al., 2021; Gibney, 2019; Moubarac et al., 2017). Finally, processed food is higher in potentially harmful additives (Martinez-Perez et al., 2021), omega-6 fatty acids (Hall et al., 2019), and sodium (Martinez-Perez et al., 2021; Wang et al., 2021). In the United States, most sodium consumption is due to commercial food processing (USDA & HHS, 2020).

The vitamin and mineral content of processed food is more nuanced. Perhaps due to fortification, Wang et al., (2021) found that processed foods are often higher in vitamin E, iron, and folic acid. In contrast, Moubarac (2017) found that iron was lower in processed foods. Despite this inconsistency, it appears that processed foods are lower in all other vitamins and

minerals, including calcium, iron, magnesium, phosphorus, potassium, zinc, niacin, riboflavin, thiamine, and vitamins A, B6, B12, C, and D (Andrade et al., 2021; Moubarac et al., 2017).

Based on this type of nutritional component analysis, the benefits of food processing appear to be compromised by areas of concern. Based on the evidence available, Elizabeth et al., (2020) stated

> The nutrition literature and authoritative reports increasingly recognize the concept of ultra-processed foods (UPF), as a descriptor of unhealthy diets... There is now a considerable body of evidence supporting the use of UPFs as a scientific concept to assess the 'healthiness' of foods within the context of dietary patterns and to help inform the development of dietary guidelines and nutrition policy actions. (p. 1)

The influence of food processing research on the dietary guidelines for Americans will be discussed in the following section.

Dietary Guidelines for Americans

The U.S. Food and Drug Administration updates the dietary guidelines for Americans every five years, but these guidelines currently do not recognize the Nova system. The guidelines use the terms “nutrient dense” vs. “typical” instead of “minimally processed” vs. “ultra-processed” (USDA & HHS, 2020, p. 22). Regardless of phrasing, the dietary guidelines for Americans seem to describe similar concepts as the Nova system. The guidelines define “nutrient dense” foods as “vegetables, fruits, whole grains, seafood, eggs, beans, peas, and lentils, unsalted nuts and seeds, fat-free and low-fat dairy products, and lean meats and poultry—when prepared with no or little added sugars, saturated fat, and sodium" (USDA & HHS, 2020, p. 95). These foods would generally be classified as unprocessed or minimally processed according to Monteiro et al. (2010). The dietary guidelines for Americans state that nutrient density is determined by how and where the item is prepared (USDA & HHS, 2020, p. 40); this

is similar to the Nova system that "groups foods according to the extent and purpose of industrial processing" (Monteiro, Cannon, Levy, et al., 2019, p. 936).

Although the dietary guidelines for Americans do not use terminology from the Nova system, they make recommendations regarding whole vs. processed foods in certain categories. The guidelines recommend that most fruit servings come from whole fruit, defined as fruit in fresh, frozen, dried, and canned forms (USDA & HHS, 2020). Similarly, the guidelines recommend that most grain servings are 100% whole grain, meaning that the only grains involved are whole grains, as opposed to refined. Vegetables are recommended in fresh, frozen, or canned varieties. The only types of processed foods that are specifically mentioned by the guidelines are processed meats, such as ham, hot dogs, luncheon meats, and sausages. The guidelines suggest limiting processed meat to less than half of the overall amount of meat and poultry consumed and replacing it with seafood, beans, peas, or lentils. Finally, the guidelines warn against overconsumption of calories from restaurant food and ready-to-eat meals due to portion size and preparation methods (USDA & HHS, 2020). All of these concepts are consistent with those described in the Nova system (Monteiro et al., 2010).

The dietary guidelines for Americans also place limits on components that are associated with ultra-processed foods. These foods tend to be high in sugar, salt, and saturated fat (Andrade et al., 2021; Hall et al., 2019; Elizabeth et al., 2020; Martinez-Perez et al., 2021; Wang et al., 2021). The guidelines limit sugar to less than 50 grams per day, saturated fat to less than 22 grams per day, and sodium to less than 2,300 mg per day. Guidelines for children younger than 2 years of age include avoiding added sugar and saturated fat completely. For ages 1-3, 4-8, 9-13, and 14 and above, salt recommendations are limited to 1,200 mg/day, 1,500 mg/day, 1,800 mg/day, and 2,300 mg/day respectively (USDA & HHS, 2020). For comparison, the dietary guidelines for Americans are stricter with salt but more relaxed with sugar, compared to the

World Health Organization. The World Health Organization recommends limiting salt to 5,000 mg per day but limiting sugar to 25 g per day (Fondevila-Gascón et al., 2022).

Cognition

The outcome variables in this study include two tests of cognition. Cognition is defined as “the mental processes involved in learning, comprehension and problem solving; it helps connect our inside world to our environment" (Gauci, 2022, p. 13). Cognition includes several domains, including attention, executive function, memory, problem-solving, processing speed, and visual-spatial skill (Gauci, 2022; Pilato et al., 2020).

If one is ultimately interested in academic achievement, cognition may be a more effective variable to study for several reasons. First, strong academic outcomes depend on a solid foundation of cognition. In addition, cognitive tests communicate information about a student’s learning capacity without the confounding effects of effort, grading policies, task difficulty, and a host of other factors that ultimately determine a final letter grade. In this way, cognition can be seen as a “purer measure,” compared to academic performance itself (Pilato et al., 2020, p. 2). Compared to course grades or standardized exams, cognitive tests have the benefits of being quick, simple, compatible with experimental design, and informative about underlying cognitive processes.

Verbal Learning

Verbal learning is just one part of the memory domain of cognition (Cardoso et al., 2022), but the term is often used synonymously with memory and recall (Gauchi et al., 2022, Sanchez-Aguadero et al., 2020; Spreen & Strauss, 1991; Tulving & Madigan, 1970). Technically, verbal learning is the ability to memorize and freely recall new verbal information (Schmidt, 1996; Spreen & Strauss, 1991). Lab-based studies of verbal learning have contributed greatly to the biological understanding of memory (Ricardo, 2022); research has revealed that

the hippocampus has a prominent role in this type of memory and learning (Fanselow & Dong, 2010; Marx 2021).

Importance. Verbal learning is an important concept in the world of education. Mathematical ability can be predicted two years in advance by using brain scans during verbal learning tasks (Dumontheil & Klingberg, 2012). Children with poor working memory tend to struggle with reading ability (Taha et al., 2022) as well as maintaining attention, monitoring their quality of work, and problem-solving (Alloway et al., 2009). At the secondary level, higher verbal learning has a significant positive relationship with intelligence and overall achievement level (Fard et al., 2016; Thomas, 2022). Undergraduate students with lower memory are less likely to stay on-task and more likely to exhibit mind-wandering (Kane et al., 2007), and verbal learning predicts overall G.P.A. in the first year (Imlach et al., 2017). Verbal learning can be considered an indicator of overall learning ability (Spreen & Strauss, 1991), so it therefore stands to reason that any factor that decreases verbal learning may negatively impact overall academic success.

Verbal learning tests are ubiquitous in neuropsychology (Hawkins et al., 2004), and they are becoming increasingly offered in computerized formats (Casaletto & Heaton, 2017; Gottlieb et al., 2022). Three commonly used verbal learning tests are the international shopping list, the Consortium to Establish a Registry for Alzheimer's Disease (CERAD) Word Learning test, and the Rey Auditory-Verbal Learning Test (RAVLT). In the international shopping list, participants have three trials to recall items from a list, after a delay (Pilato et al., 2020). The CERAD Word Learning test also includes three trials of attempted recall of a list of ten unrelated words, as well as a delayed trial (Cardoso et al., 2022).

RAVLT. The Rey Auditory-Verbal Learning Test (RAVLT) is a brief instrument that measures verbal learning. In this test, 15 words are spoken to the participant with a one-second

delay between words. It consists of five learning trials (A.1–A.5) that are preceded by the reading of a stimulus list (List A), one interference trial (B.1) preceded by an interference or distractor list (List B), one postdistractor trial (A.6) to measure retention of list A after the interference of list B, a 20-minute delay, one trial to measure delayed recall of list A (A.7), and a recognition test in which participants identify List A words from a set of 50 words including List A, List B, and 20 semantically and/or phonemically similar words (Denhart, 2018; Hawkins et al., 2004; Spreen & Strauss, 1991).

The number of list A words recalled during trial A.1 is known as immediate memory. The sum of words recalled in trials A.1–A.5 provides a total recall score (Spreen & Strauss, 1991, p. 151; Hawkins et al., 2004, p. 100). This total recall measure is preferable over individual learning trial scores due to increased reliability (Hawkins et al., 2004, p. 105). The number of list B words recalled during trial B.1 is known as the interference or list B score (Hawkins et al., 2004). The decrease in score from trial A.1 to B.1 is known as proactive interference; it measures the negative impact of learning list A on learning list B (Spreen & Strauss, 1991). The number of list A words recalled during trial A.6 is the post-interference list A recall score, also known as retention or intermediate memory. The decrease in score from trial A.5 to A.6 is known as retroactive interference; it measures the negative impact of learning list B on memory of list A. It can be conceptualized as the proportion of list A words lost from trial A.5 to A.6 (Denhart, 2018; Hawkins et al., 2004; Spreen & Strauss, 1991).

Reliability. Multiple forms of evidence support the reliability of the RAVLT. This test has demonstrated an excellent Cronbach's alpha of .80 (de Sousa Magalhães et al., 2012). Four similar, but not identical, forms of the RAVLT are found in Lezak (1983) and Shapiro and Harrison (1990). As detailed in Table C1 in Appendix C, the words in each of the four versions are similar in word usage frequency and mean length of words used (Hawkins et al., 2004, p.

101). Comparing versions one and two, Delaney et al. (1992) found alternative form correlation coefficients ranging between .61 to .86 for individual trials. Ryan et al. (1986) found learning trial and post-interference trial mean scores differed by less than one point. Mean total recall scores differed by less than 3 points, resulting in an alternative form reliability coefficient of r = .77 (Ryan et al., 1986).

Shapiro and Harrison (1990) compared all four versions of the RAVLT used in this study. Their findings are particularly relevant because they studied an undergraduate population with a mean age of 19 years. These authors used a mean interval of five days between tests, similar to the timeframe of one week in the present study. Shapiro and Harrison (1990) found that learning trial and post-interference trial mean scores differed by less than one point among the four versions. Alternative form correlation coefficients for individual trials ranged from .67 to .90, with a mean of .80 (Shapiro & Harrison, 1990).

Verbal Fluency

Verbal fluency tests are quick, simple assessments in which participants are asked to list as many words as they can that fit a given criterion, within a given timeframe (Cohen, 2020). These tests are also known as word fluency, Thurstone Word fluency, and Controlled Oral Word Association (COWA) tests (Strauss et al., 2006). They have been used for almost a century, originating with Thurstone (1938). Verbal fluency tests include two varieties: semantic fluency and phonemic fluency (Shao et al., 2014). Semantic fluency, also known as category fluency, involves stating words that fit into a given category (e.g., animals). Phonemic fluency, also known as letter frequency or FAS-Test, involves stating words that start with a given letter of the alphabet. Participants are given one minute to list as many words as possible that fit the stated criteria; the number of unique correct words is the final score (Shao et al., 2014).

Benefits. Verbal fluency tests are beneficial for several reasons. They efficiently screen for general verbal functioning (Shao et al., 2014). They are described as a “mainstay” of neuropsychology (Cohen, 2020, p. 3); they are frequently used in research and clinical practice, where they are used to diagnose ADHD (lack of executive control) and cognitive impairment (Cohen, 2020; Shao et al., 2014). In fact, verbal fluency may have greater sensitivity than other tests to detect executive dysfunction. These tests do not have a low ceiling, so they can be used in a variety of settings (Strauss et al., 2006).

These tests have varying degrees of relevance to day-to-day life. Similar to a semantic fluency task, the creation of a shopping list involves thinking of subcategories of food and producing items that fit several criteria (Shao et al., 2014). Like impulse control in other situations, executive control is needed to control impulses of words that rise to conscious awareness due to their association with previous words, even though they do not begin with the same letter (Shao et al., 2014). Nevertheless, the phonemic fluency test itself is not likely to be imitated by the participant in everyday life.

Procedures. In the phonemic fluency test, the participant sits comfortably, and the researcher explains the procedure. The researcher explains that a letter of the alphabet will be stated, and the participant is to give as many words as possible as quickly as possible that begin with that letter. The researcher tells the participant not to use proper names or the same word with different endings (e.g., horse and horses); examples and non-examples are provided. When the researcher states the first letter (e.g., F), the participant starts producing words and continues for one minute. The same procedure is typically repeated with two other letters (e.g., A and S) to calculate a total score (Balogh et al., 2023; Strauss et al., 2006). FAS is the most commonly used letter grouping that originated with Benton (1968), but studies have also used CFL, PRW, BHR, BDT, and MS (Dikmen et al., 1999; Shao et al., 2014; Strauss et al., 2006).

A similar procedure is conducted in the semantic fluency test. The researcher begins by stating examples of things that can be found in the kitchen. Then, the researcher asks the participant to provide the names of as many animals as possible, as quickly as possible. The participant produces words for one minute. A single trial is usually used, but three trials with different categories (e.g., food and clothing) may be used to increase reliability (Strauss et al., 2006). The most commonly used category is animals. Alternate categories include first names, boys' names, girls' names, fruits and vegetables, fruits specifically, vegetables specifically, jobs, furniture, musical instruments, things in the kitchen, things in the supermarket, things to get you from one place to another, and actions that people do (Balogh et al., 2023; Shao et al., 2014; Strauss et al., 2006).

Scoring. In the semantic fluency test, repetitions are acceptable if words have multiple meanings (e.g., "son" and "sun") (Strauss et al., 2006). Proper names, wrong words, variations, and repetitions are not counted toward the overall score (Strauss et al., 2006). Extinct, imaginary, and magic animals are acceptable, but given names like "Fido" are not (Strauss et al., 2006). Balough et al. (2023) suggest only giving one point for synonymous words (e.g., bunny and rabbit), gender variations (e.g., rooster and hen), and offspring relationships (e.g., dog and puppy). Similarly, if subcategories and specific examples are given (e.g., insect and mosquito), points are only awarded for each example (Balogh et al., 2023). Age-based normative data are available for animals (7–95), food (6–12, 60+), fruit (50–79), vegetables (50–79), and clothing (60+) (Strauss et al., 2006). Scores tend to stabilize around age 11–12 with a steady decline from age 20 on (Strauss et al., 2006).

In the phonemic fluency test, slang terms and foreign words used in standard English are acceptable (e.g., "lasagna, faux pas") (Strauss et al., 2006). However, points are not given for incorrect words, variations of the same word, and repetitions (Strauss et al., 2006). Age-based

normative data are available FAS, (ages 7-95), CFL (6-97), and PRW (6-12). Scores tend to peak around age 30-39 (Strauss et al., 2006).

In addition to the total score, some authors also analyze other variables that originate from fluency tests. These include repetitions, known as perseverations, and words that do not fit the given criteria, known as intrusions (Balogh et al., 2023). Clustering and switching can also be analyzed. In semantic fluency, clustering is listing several examples within the same subcategory in a sequence (e.g., eagle, hawk, sparrow). In phonemic fluency, clusters include words that start with the same two letters, differ only by a vowel sound, or are homonyms. Cluster size is recorded as the count of words in a given cluster, starting with the second word. Clustering is a relatively automatic process involving phonemic analysis and semantic categorization in the temporal lobe (Strauss et al., 2006). Switching is moving on to a new subcategory or cluster. Switching is recorded as the number of transitions between clusters, including single words. Switching is a more difficult process involving cognitive flexibility in the frontal lobe (Strauss et al., 2006).

Concepts Measured. There has been ongoing discussion about what precisely is measured by verbal fluency tests. Both of these tests clearly evaluate the spontaneous word production given limiting criteria. However, only moderate correlations exist between phonemic and category fluency (r = .34-.64), suggesting that different processes may be involved in each test (Strauss et al., 2006). They are both thought to evaluate verbal ability and executive function to a certain degree, as well as episodic memory, processing speed, word knowledge, and working memory (Shao et al., 2014, Strauss et al., 2006; Whiteside et al., 2016). Verbal ability is relevant due to the need to retrieve words. Executive control is relevant in the need to regulate thoughts and behavior to meet the goal of the test, such as applying filters to select which words fit the criteria without duplication (Shao et al., 2014).

There is disagreement about the relative contribution of executive and verbal ability to categorical and phonemic fluency. Clinical and neuroimaging studies imply that executive ability is a stronger determinant of phonemic fluency, whereas verbal ability is a stronger determinant of semantic fluency (Strauss et al., 2006). However, a factor-analytic study implied that both phonemic and categorical fluency tests are primarily tests of language ability, as opposed to executive function (Whiteside et al., 2016). In order to increase the relative contribution of executive function, some authors have suggested asking participants to alternate categories for each response (Strauss et al., 2006). Regardless, analysis of verbal fluency should reflect the fact that each test has a "hybrid nature" and therefore is not a "pure measure" of executive function or verbal ability (Shao et al., 2014, p. 2).

Validity and Reliability. Verbal fluency tests have a strong record of validity and reliability. Regarding internal reliability, coefficient alpha is high (r = .83) for both FAS and CFL forms (Ruff et al., 1996; Tombaugh et al., 1999). Test-retest reliability correlations tend to be high, above .70, for both phonemic and semantic tests with one-week and five-year intervals, implying that these tests can be used to track changes in the same individual (Strauss et al., 2006). If the same letter or category is re-used, a small gain is evident (Wilson et al., 2000). Bird et al. (2004) observed a small but consistent practice effect with a test-retest reliability of r = .56 and r = .63 for animals and the letter S, respectively. Similarly, Smerbeck et al., (2023) observed a small practice effect with average gains of 1.62 and 3.52 words after one and four retests, respectively. However, test-retest reliability is generally low when specifically examining clustering and switching outcomes (Strauss et al., 2006).

Regarding phonemic alternate form reliability, the data generally show that various forms are roughly equivalent. Granted, starting letters do vary in difficulty and word frequency (Strauss et al., 2006). However, with a counterbalanced analysis of FAS and BDT forms, Dikmen et al.

(1999) observed an adequate alternate form reliability of .72 with a small practice effect. Schum et al. (1989) observed only minor score differences between the CFL and PRW forms; these forms had a correlation of .74 (Ruff et al., 1996). Correlations are .82 and .83 for CFL vs PRW and FAS vs. BHR, respectively (Benton et al., 1994; Delis et al., 2001). FAS and CFL forms generally have correlations between .85-.94 across various settings (Strauss et al., 2006).

There are fewer studies of alternate form reliability in semantic fluency tests (Cohen, 2020). Correlations of various categories are moderately high at .66-.71 (Delis et al., 2001; Riva et al., 2000). Cunje et al. (2007) found that tests of animals, cities and towns, and fruits and vegetables, did not differ significantly and therefore had adequate equivalence to be used in serial testing. Scores for cities and towns were slightly higher, so a correction factor of -4 was suggested to bring the averages down to those of the other tests (Cunje et al., 2007). Scores for first names were significantly higher and therefore were not recommended to be used as an alternate form (Cunje et al., 2007). Cohen (2020) reported strong alternate form reliability (r = .67-.76) using animals, fruits and vegetables, and musical instruments as categories. The results informed the selection of alternative forms for this study.

Context

Current Status of Diet Quality and Food Processing

Diet Quality in the U.S. Overall diet quality in the United States is poor (Wilson et al., 2016). Health-related risk factors in the U.S. include a lack of fruits, vegetables, whole grains, nuts, seeds, fiber, and calcium, and an excess of processed meats, sodium, and trans-fat (Afshin et al., 2019). Approximately 88% of youth and adults in general do not consume the recommended amounts of fruits and vegetables (Lee-Kwan et al., 2017; Moore et al., 2017). Greater than 90% of women and 97% of men do not consume the recommended amount of fiber. Americans generally consume the recommended number of grain products in general, but 98%

of Americans do not consume the recommended servings of whole grains (USDA & HHS, 2020).

The U.S.D.A.'s Health Eating Index (H.E.I.) is often used in research as a measure of overall diet quality. H.E.I. scores average 61 out of 100 for ages 2-4, drop to their lowest level of 51 in ages 14–18, rise to 56 in ages 19-30, and continue rising to 63 in ages 60+ (USDA & HHS, 2020). These overall scores are based on national guidelines from 2015. As such, the Healthy Eating Index provides positive scores for any meat products, with no recognition of the World Health Organization's classification of red meat and processed meat as carcinogens (Anderson et al., 2018; IARC, 2015) or the demonstrated connection between increased processed meat consumption with increased all-cause mortality (Zeraatkar et al., 2019). Therefore, the true nutritional quality status in America may be lower than it would appear from this data.

Statistics of Processed Food Consumption. Roughly half of the calories in the Western world are consumed in the form of ultra-processed food (Baraldi et al., 2018; Monteiro et al., 2013; Moubarac et al., 2017; Rauber, 2020; Rauber et al., 2018; Martínez Steele et al., 2016). Estimates vary widely by country: 10% in Italy (Marino et al., 2021), 22% in Brazil (Andrade et al., 2021), 23% in Israel (Weinstein et al., 2023), 26–27% in South Korea (Shim et al., 2021; Sung et al., 2021), 31% in France (Andrade et al., 2021), 34–56% in Australia (Coyle et al., 2022; Machado et al., 2019 Whatnall et al., 2022), 57% in the UK (Marino et al., 2021; Rauber et al., 2019), and 31–60% in the USA (Andrade et al., 2021; Baraldi et al., 2018; Juul et al., 2022; Martínez Steele et al., 2016; Martínez Steele et al., 2017). In a large, nationally representative sample of American adults at least 20 years of age: 55% of calories came from ultra-processed food with a quartile 1 midpoint of 40.4% and a quartile 4 midpoint of 70.5% (Zhang et al., 2021). This estimate is consistent with a meta-analysis that found an average of 56% of calorie consumption from ultra-processed food in the United States (Lane et al., 2021).

Processed and ultra-processed food consumption appears to be rising across the globe (Baker et al., 2020; Jacka et al., 2015; Monteiro et al., 2013; Pagliai et al., 2021; PAHO, 2015; Shim et al., 2021). In a representative sample of Americans, ultra-processed food consumption increased for all age groups from 2001 to 2018 from 53.5% to 57% of total calories consumed (Juul et al., 2022). This pattern is consistent for children, adolescents, and adults over age 60 (Wang et al., 2021). The fastest-growing sector of ultra-processed food is ready-to-eat/heat meals (Juul et al., 2022). Baker (2020, p. 1) commented that “the scale of dietary change underway, especially in highly populated middle-income countries, raises serious concern for global health.”

Not all aspects of food processing have a straightforward, growing trend. For example, the status of sugar-sweetened processed foods is more complicated. Those living in the United Kingdom and the U.S.A. obtain 65% and 90% of their sugar from ultra-processed foods, respectively, and those numbers appear to be even higher for adolescents (Martínez Steele et al., 2016; Rauber et al., 2019). Even though the consumption of sweet snacks and sweets increased over the last two decades, sweetened beverage consumption was cut in half. This resulted in an overall decrease in added sugar during that time period (Shan et al., 2019; Wang et al., 2021).

Demographic Patterns of Processed Food Consumption. Statistics related to the consumption of processed foods appear to vary by several factors, including age. Young people, men, and those who are overweight tend to have the highest consumption of ultra-processed foods (Andrade, 2021; Marino et al., 2021; Moubarac et al., 2017; Shim et al., 2021). Martínez Steele et al. (2020) found a statistically significant decreasing trend in ultra-processed food consumption with age, such that 68% of calories originated from ultra-processed food in children aged 6–11 years, followed by 67% in 12–19-year-olds, followed by 56% in adults 20 years or older. These estimates are consistent with other data that show a similar age-based trend (Baraldi

et al., 2019; Juul et al., 2022; Wang et al., 2021). The trend of higher ultra-processed food consumption in children and young adults is consistent with data showing that young Americans spend a greater portion of their food dollars on prepared foods than older generations (USDA & HHS, 2020). Similar age-based trends can be seen worldwide (Andrade et al., 2021; Howarth et al., 2007; Marino et al., 2021; Rauber et al., 2020; Shim et al., 2021; Sung et al., 2021).

Consumption of processed food also has trends based on race and ethnicity. Ultra-processed food consumption is currently lower in Hispanic people (Baraldi et al., 2018; Juul et al., 2022), but rising at a faster rate, compared to non-Hispanic white people (Wang et al., 2021). Consumption of ultra-processed food is highest in non-Hispanic Black youth (73% of total calories) with a faster increase than Mexican American (64%) and non-Hispanic White (69%) youth.

Consumption of processed foods also generally trends with socioeconomic status and education. Ultra-processed foods compose a higher proportion of total calories in urban areas (Andrade et al., 2021; Shim et al., 2021). Within the United States, there is a greater proportion of ultra-processed food consumption by those with low income (Baraldi et al., 2018, Darmon & Drewnowski, 2015). A similar trend was observed in Australia (Coyle et al., 2022), but the opposite trend was observed in South Korea (Shim et al., 2021). Similarly, ultra-processed food consumption is associated with a lower education level in the United States, (Baraldi et al., 2018; Juul et al., 2022), but this trend is not necessarily consistent worldwide (Shim et al., 2021).

Reasons Behind Trends. The global increase in processed food consumption is likely due to many factors, but it is likely driven by convenience, attractiveness to the consumer, addictive properties, competition on the industry level, economic factors, targeted marketing of minorities, and more recently, the COVID-19 pandemic (Baker et al., 2020; Coletro et al., 2022; Monteiro et al., 2013; Wang et al., 2021; Whatnall et al., 2022). One intuitive reason for the

global increase in processed food consumption is the addictive nature of the ingredients. Consumers are particularly likely to be addicted to processed foods that are characterized by rapid absorption and high doses of pleasure-inducing compounds (Schulte et al., 2015). As foods become more and more processed, there is a greater potential for increasing the concentration and strength of addictive compounds. Ultra-processed food consumption was correlated with increased food addiction in a sample of 735 Australian young adults. Roughly 20% of the sample was food addicted, and those who were food addicted consumed significantly more ultra-processed food and less minimally processed food than those who were not (Whatnall et al., 2022).

It is not entirely clear how economic factors play into these global trends. Pagliai et al. (2021) found that ultra-processed food consumption has increased worldwide, regardless of economic status. However, Baker et al. (2020) observed a pattern that as countries become richer, larger quantities and a greater variety of ultra-processed foods are sold. Darmon and Drewnowski (2015) indicated that ultra-processed food is cheaper per calorie, and Blum et al., (2022) wrote that the processed food supply chain is cheaper by nature. However, Hall et al. (2019) reported that the ultra-processed meals used in their study were 42% more expensive than their minimally processed meals. Although certain unprocessed and minimally processed ingredients may be inexpensive, the time and expertise to prepare those foods into meals can be a limiting factor, especially for those in lower socioeconomic classes (Hall et al., 2019).

For those with limited financial resources, the struggle to acquire and prepare healthful food is especially intense. Those with do not live within close distance to a supermarket (and/or lack the transportation to get there) live in locations known as *food deserts*. The technical definition of a food desert is a low-income census tract in which a third of the population fits this criterion (Frndak, 2014). These food deserts are especially prevalent in minority communities

(Adams et al., 2010) and affect a fifth of kindergarten children in low-income households (Wang & Black, 2019).

These racial and socioeconomic challenges with food access have far-reaching effects, from birth to death. Lipsitz (1998) identified malnutrition as one of the hidden causes behind the lower life expectancies plaguing minorities (as cited in Adams et al., 2013, p. 81). These differences appear to impact a baby's growth in the first year of life (Wen et al., 2014). Food insecurity in general has a significant direct relationship with self-rated health, as well as a significant indirect relationship with health through social status (Willis, 2021).

Children and youth are particularly vulnerable to the global rise of ultra-processed foods. Marketing tactics of ultra-processed food target adolescents intensively (Andrade et al., 2021), and it can be difficult to change food preferences and dietary patterns that are set in childhood (Elizabeth et al., 2020; Sorhaindo & Feinstein, 2006; U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2020). For example, eating practices in the first 1000 days of life are associated with the consumption of processed food in adulthood. Those who habitually eat fewer fruits and vegetables as a child eat less minimally processed food as an adult. On the other hand, delayed introduction of formula or other forms of milk was associated with lower ultra-processed food consumption as an adult (da Costa Penha et al., 2022). These early eating experiences have additional ramifications as a child grows. In a study of college students, those who did not experience a variety of foods as children had greater food neophobia as adults; these students subsequently consumed less calcium, potassium, and vitamin C than those without food neophobia (Lunsford, 2022).

College Diet Quality

Regarding the specific context of the present study, the overall diet quality of college students is poor (Cervera Burriel et al., 2013; Duran et al., 2017; Parsons et al., 2022; Shi et al.,

2022), especially compared to other stages of life (Imamura et al., 2015; Shan et al., 2016). In the U.S., the majority of young adults exceed the recommended intake limits of added sugar (66% of females and 62% of males), saturated fat (71% of females and 76% of males), and sodium (84% of females and 97% of males) (USDA & HHS, 2020). College students, especially males, are generally deficient in vegetable intake (Blum et al., 2022; Mello Rodrigues et al., 2019), and one study indicated that 83% of college students did not meet fruit and vegetable recommendations (Peltzer & Pengpid, 2015).

Regarding food processing, specifically, college-age students in the U.S.A. receive roughly twice as many calories from ultra-processed food as opposed to minimally processed food (Juul et al., 2022). A nationally representative cross-sectional study found that college student consumption of ultra-processed foods is greater than the national average (Martínez Steele et al., 2016), and consumption at this stage of life is high worldwide (Andrade et al., 2021; Capra, 2022; Schnettler et al., 2015). There are many potential reasons for this phenomenon, including affordability, accessibility, palatability, and convenience (Blum et al., 2022).

College students are in a stage of life with unique challenges for healthy eating and wellness in general. Young adults' brains are not yet fully developed, leading to ignoring of risks associated with their choices (Hochberg & Konner, 2020). For example, college students tend to have low physical activity and sleep combined with relatively high tobacco use (Duran et al., 2017). *Emerging adulthood* has been proposed as a distinct life history stage for 18–25-year-olds, due to this incomplete physical and social maturation (Hochberg & Konner, 2020). This season of life is characterized by major life changes that can also create barriers to wellness and healthy eating (Munt et al., 2017; Winpenny et al., 2018). Some of the barriers are described below.

Limited Time. One of the greatest barriers to healthy eating in college is lack of time. Young adults in general can struggle to balance responsibilities with family, friends, school, and work, leading to tight schedules (Blum et al., 2022; USDA & HHS, 2020). College is often characterized by limited time to eat meals or skipping meals altogether. This time pressure lends itself to ready-to-eat ultra-processed meals (Schnettler et al., 2015). To fill this need for quick food, college settings are frequently characterized by high availability and visibility of processed foods (Fondevila-Gascón et al., 2022).

Social Context. The social context of college can be a double-edged sword for dietary health and wellness. The college social context favors sedentary activities in general, but those who participate in sports tend to self-report a healthier diet (Fondevila-Gascón et al., 2022). Eating dinner, in general, is a protective factor for the social domain of college students' quality of life (Lanuza et al., 2022). However, if that dinner occurs outside the home, the meal tends to be low in nutritional value and high in calories, potentially compromising its value in the physical domain (Watts et al., 2017).

Diet Management Inexperience. An additional barrier in this life stage is inexperience with managing one's own diet. College may be the first time that many young adults take ownership of finding and preparing food for themselves and monitoring their own nutrition (Fondevila-Gascón et al., 2022; Verger et al., 2009). In a sample of college students, over 60% of participants did not read nutrition facts, ingredients, or expiration dates; this ignorance leads to false perceptions that they know how to perceive the processing level of various foods and a distorted view of the typical Western diet as "normal" or "very healthy" (Fondevila-Gascón et al., 2022, p. 13). As a result, college students who do not live with their families consume significantly more ultra-processed food than those who do (Fondevila-Gascón et al., 2022). Experience with acquiring and preparing food may counteract the pitfalls of this season of life.

For example, college students who perceive that they have good cooking skills tend to have higher diet quality (Shi et al., 2022).

Food Insecurity. The last major barrier to healthy eating in college students is food insecurity. Despite the potential to be more affluent than their non-college-bound peers (Peltzer & Pengpid, 2015), college learners are not immune to the impacts of food insecurity (Blum et al., 2022; Willis, 2021). Estimates of food insecurity in university settings range from 15%-42% (Bruening et al., 2017; Maciel et al., 2022; Payne-Sturges et al., 2018; Willis, 2021), and minority students are particularly vulnerable to food insecurity (Maciel et al., 2022). College students with food insecurity have a significantly lower-quality diet, compared to food-secure students (Maciel et al., 2022; Shi et al., 2022). College food insecurity is associated with higher ultra-processed food consumption, which may exacerbate health and wellness concerns (Bruening et al., 2017; Maciel et al., 2022).

The reasons behind college food insecurity are multifaceted. Anderson et al. (2022) wrote that college food insecurity

> cannot be conceptualized as an isolated phenomenon, but rather a deeply complex reality with intersecting layers of influence from individual level lived experiences and perceived meaning of [food insecurity], to institutional and familial facilitators to food access, to larger structural and social barriers. (p. 15)

Limited finances have been identified as an intuitive cause of poor eating in college (Blum et al., 2022), and this factor was likely exacerbated by COVID-19 and the economic volatility that followed its arrival. In one study of college students, 48% of the participants lost income during the COVID-19 pandemic (Maciel et al., 2022). Social networks and access to resources on campus can help ameliorate the problem, but social comparison and stigma may also play a role in keeping students from accessing affordable, healthy food (Anderson et al., 2022).

Nevertheless, college food deserts persist, despite efforts to address their prevalence (Blum et al., 2022).

Food insecurity has a ripple effect on the lives of students. First, it has a significant relationship with mental health in college students (Goldrick-Rab et al., 2015); food-insecure students have significantly higher rates of depression (Willis, 2021). It has also been suggested that light meals and food insecurity in general may have far-reaching impacts on social standing, grades, and graduation rates (Herrero Lozano & Fillat Ballesteros, 2006; Payne-Sturges et al., 2018; Willis, 2021). A systematic review revealed that food insecurity is consistently associated with poor outcomes (Bruening et al., 2017); food insecurity negatively correlates with academic performance on a national scale (Wang & Black, 2019).

Connections

Diet quality has a significant relationship with overall quality of life in college students (Lanuza et al., 2022), affecting their physical, mental, and psychological development (Sánchez-Ojeda & Luna-Bertos, 2015). Nutrition can be studied at various levels, including individual nutrients, whole foods, dietary patterns, and the broad classification of degree of food processing. Similarly, each level of nutritional organization can have a potential impact on several interrelated outcome variables, including physical health, mental health, academic performance, and cognition. This review will briefly summarize some of the key connections that have been demonstrated between these nutritional levels and outcome variables.

Food Component Outcomes

Historically, food components have been the most heavily studied level of nutrition (Messina et al., 2001; Sorhaindo & Feinstein, 2006). In addition to macronutrients such as carbohydrates, lipids, proteins, and nucleic acids, several other micronutrients, additives, and other dietary components have been studied for their potential impacts on health and cognition.

Physical Health. The dietary guidelines for Americans limit sodium, saturated fat, and sugar based on evidence of adverse health outcomes. Added sugar contributes to excessive calories, and elevated sodium has been demonstrated to increase the risk of hypertension and cardiovascular disease (USDA & HHS, 2020). The majority of saturated fats in the American diet come from meat and dairy (American Heart Association, 2020); saturated fats are associated with an increased risk of cardiovascular disease events (Hooper et al., 2020) and have a causal role in the development of type II diabetes (Kraegen & Cooney, 2008).

In addition to the three components specifically limited by the dietary guidelines for Americans, a host of other molecules have been linked to negative health outcomes. Two compounds that originate from plastic packaging, bisphenol A and bisphenol S, are associated with cardiometabolic disorders and endocrine system damage, respectively (Pagliai et al., 2021; Rancière, 2015). Acrylamide and acrolein, produced when different types of foods are heated, have demonstrated connections to increased cardiovascular disease (Pagliai et al., 2021; Zhang et al., 2018). Trans fatty acids contribute to inflammation, oxidation, atherosclerosis, and damage to glucose control (Iwata et al., 2011).

Other molecules have more beneficial effects. Phytochemicals from plant foods are associated with an overall lower risk of chronic disease (Liu, 2003). Polyphenols are a group of phytochemicals with antioxidant, and anti-inflammatory properties (Berding et al., 2021) that regulate lipid metabolism (Miranda et al., 2022) and support a healthy gut microbiome (Berding et al., 2021). Plant foods are major sources of antioxidant and anti-inflammatory compounds that also help prevent the number one killer of Americans, cardiovascular disease (Jain et al., 2018).

Lastly, food components also appear to be a major causality of COVID-19 outcomes (Jayawarden & Misra, 2020). Supposedly due to the impact of dietary antioxidants, fermented vegetable consumption correlates with a lower COVID-19 death rate on a national scale

(Fonseca et al., 2020). In addition to antioxidant capacity, certain dietary components appear to up-regulate or down-regulate the protein receptor ACE-2 (angiotensin-converting enzyme 2), the cellular gateway to which the virus attaches to gain entry (Bosquet et al., 2020). Broccoli protein down-regulates ACE (Dange et al., 2019), whereas saturated fat increases it (Schuler et al., 2017). Other dietary connections to greater infectious disease risk may be discovered over time.

Cognition. Some of the same dietary components connected to physical health also have demonstrated connections to cognitive function (Sorhaindo & Feinstein, 2006). For example, glucose has clear causal impacts on over 10 measures of cognition (Bellisle, 2004). Ultra-processed meat and fat contain advanced glycation end products (Uribarri et al., 2010) that are associated with a faster decline in cognition (West et al., 2014; Yaffe et al., 2011). Higher dietary sodium in adults age 50+ correlates with lower cognitive function (a combined index of verbal learning, executive function, attention, and calculation), whereas higher potassium correlates with higher cognitive function. The authors found that replacing 1000 mg of sodium with potassium increases cognitive test scores by about 4% (Na et al., 2022). The type of fat we consume may be important for cognition as well. Trans fatty acids are associated with dementia and Alzheimer's Disease (Barnard et al., 2014), but polyunsaturated DHA and EPA appear to have a positive impact on cognition. In a double-blind randomized controlled trial of adults over age 61, those who consumed fish oil rich in DHA/EPA reported a reduction in adverse cognitive symptoms with a large effect size (McNamara et al., 2018).

Flavonoids are a group of phytochemicals that have a particularly promising impact on cognition. There is evidence that flavonoid consumption improves cognition in children, adults, and the elderly (Berding et al., 2021; Leber et al., 2022). Within this class, flavanols, flavanones, and anthocyanins appear to have the greatest impact on brain health (Kent, Charlton, Roodenrys, et al., 2017). In a 12-week-long intervention with nine adults with mild memory decline (average

age of 76 years), blueberry juice improved paired associate learning memory with a large effect size (Cohen's *f* = .48) (Krikorian, Shidler, et al., 2010). A similar intervention with cherry juice in older adults with dementia revealed improved short- and long-term memory and verbal fluency (Kent, Charlton, Roodenrys, et al., 2017). In similar randomized controlled trials with adults over age 67 with cognitive impairment, anthocyanin consumption improved verbal fluency and short- and long-term memory. Consistent results were found in children and young adults with cognitive impairment; four acute crossover trials revealed that anthocyanins improved processing speed, attention, working memory, and response inhibition (Kent, Charlton, Netzel & Fanning, 2017).

The connection between flavonoids and increased cognition is not limited to those with pre-existing cognitive impairment. The Nurse's Health study of over 16,000 participants revealed that slower global cognitive decline was associated with greater intake of anthocyanins and total flavonoids (Devore et al., 2012). An 8-week long double-blind randomized controlled trial of healthy adults over age 60 revealed that cocoa flavanol consumption resulted in better executive functioning and verbal fluency (Mastroiacovo et al., 2015). A review of randomized controlled trials in older adults with mild-to-no cognitive impairment also found that berry supplements improve attention, executive function, memory, and processing speed (Bonyadi et al., 2022).

Within the realm of cognition, several dietary components have specifically been studied for their proposed impact on verbal learning. In a randomized double-blind controlled trial of well-nourished Australian school-age students, 12 months of supplementing with micronutrients such as iron, zinc, vitamin A, folate, vitamin B-6, vitamin B-12, and Vitamin C improved verbal learning with an effect size of .23 (Osendarp et al., 2007). Sodium also appears to have a negative impact on verbal learning scores. In the previously discussed study by Na et al. (2022),

74% of the cognitive index tested verbal learning, in addition to 7% executive function and 19% attention and calculation.

Verbal learning positively correlates with the consumption of various types of polyphenols found in plant foods, particularly flavonoids (Miranda et al., 2022). In 12–16-week randomized controlled trials, anthocyanins improved verbal learning in four acute crossover trials in children, young adults, and adults over age 67 with cognitive impairment (Kent, Charlton, Netzel & Fanning, 2017). After 12 weeks of consuming 200 mL of anthocyanin-rich cherry juice, adults over age 70 with dementia saw improved RAVLT scores. The authors observed moderate to large effect sizes for delayed ($\eta 2 = 0.242$) and total ($\eta 2 = 0.713$) RAVLT scores (Kent, Charlton, Roodenrys, et al., 2017).

However, not all studies on flavonoids indicated consistent positive effects on verbal learning. Caldwell et al. (2016) found that anthocyanin-rich cherry juice had no effect on RAVLT scores, and Krikorian, Nash, et al. (2010) found no impact of grape juice on verbal learning, using the California Verbal Learning Test II. In a crossover trial of 8–10-year-old children, a blueberry drink improved delayed verbal recall but also increased proactive interference, the decremental impact of learning list A on list B (Whyte & Williams, 2015). Therefore, it is unclear whether or not anthocyanins truly have a consistent positive impact on verbal learning.

Whole Food Outcomes

Although more research has been performed on individual food components than foods, several authors have recommended moving beyond nutrient reductionism to consider the impact of whole foods (Jacobs et al., 2011; Jacobs & Steffen, 2003; Kent, Charlton, Netzel & Fanning, 2017; Messina et al., 2001; Pistollato & Battino, 2014; Tapsell et al., 2016). It is well-documented that fruit and vegetable consumption has correlated with increased academic

performance (Bradley & Greene, 2013; Doku et al., 2013; Neumark-Sztainer et al., 1996; Peltzer & Pengpid, 2015) as well as improved happiness in college students (Lesani et al., 2016).

In addition to academic performance and mental health, specific foods also have demonstrated connections to cognition. Pilato et al. (2020) examined connections between various foods and aspects of cognition in college students. They found that increased fruit consumption positively correlates with increased visual memory, and seafood consumption positively correlates with increased paired associative learning (learning and remembering pictures hidden under different locations). In addition, eggs, beans, and fluid consumption on testing day were associated with increased verbal memory (Pilato et al., 2020). Green leafy vegetables appear to be particularly beneficial for cognition. A longitudinal study of adults at least 58 years old revealed that an average of 1.3 servings of green leafy vegetables per day was associated with less cognitive decline, equivalent to being 11 years younger; this model was adjusted for age, alcohol and seafood consumption, education, physical activity, smoking, and sex (Morris et al., 2018).

Berry foods, specifically, have demonstrated positive connections to various aspects of cognition. A large longitudinal cohort study revealed that berry consumption may delay cognitive aging by up to 2.5 years (Devore et al., 2012). In a double-blind randomized controlled trial of adults over 61, blueberry consumption resulted in a reduction in self-assessed cognitive symptoms with a large effect size of $f > .4$ (McNamara et al., 2018). Bonyadi et al., (2022) recommended consuming berries in their whole form due to their positive impact on attention, resting brain perfusion, executive function, memory, and processing speed in older adults with mild-to-no cognitive impairment. There is also evidence that berries may benefit verbal memory specifically. In a 16-week randomized, placebo-controlled trial, older adults who consumed a

blueberry meal had higher activation of the area of the brain involved in verbal memory (Boespflug et al., 2018).

Dietary Pattern Outcomes

Physical Health. Whole foods are not consumed in isolation, so it is recommended to also study overall patterns of food consumption (Jacobs et al., 2011; Messina et al., 2001; Tapsell et al., 2016). It is well-known that overall diet impacts physical health (NRC, 1990); poor nutrition is the single most important factor contributing to years of life lost or lived with disability (Murray et al., 2013; Afshin et al., 2019). Large-scale epidemiological cohort data indicates that those who habitually eat foods with poor Nutri-Score ratings (low in protein, fiber, legumes, nuts, and unsaturated fat but high in sodium, sugar, saturated fat, and overall calories) have a higher risk of weight gain, asthma, metabolic syndrome, cardiovascular disease, cancer, and all-cause mortality (IARC, 2021). The Western-style diet, high in processed food and sugar while low in fruits and vegetables, is pro-inflammatory (Więckowska-Gacek et al., 2021) and has possible connections to increased obesity (Marx et al., 2021), cardio-metabolic problems (Drake et al., 2018), and the gut microbiome (Berding et al., 2021).

On the other hand, alternative dietary patterns have demonstrated clear physical health benefits. The evidence is growing that diverse, whole-food, plant-based dietary patterns low in red meat and processed foods are healthy alternatives to the Western diet (Gauci, 2022). In college-age males, the Mediterranean diet has a negative correlation with abdominal girth, body mass, body mass index, body fat percentage, blood pressure, fasting blood glucose, and waist-to-hip ratio (Prieto-González et al., 2022). Plant-based diets in general appear to be protective against metabolic syndrome and neurodegenerative diseases (Pistollato & Battino, 2014). In a randomized controlled trial, a 10% fat whole food vegetarian diet, along with other lifestyle

changes, demonstrated the ability to not only prevent but reverse the number one killer of Americans, heart disease (Ornish, 1998).

Mental Health. In addition to physical health, dietary patterns are also connected to mental health. The Western diet is associated with greater mental distress, whereas other diets have the opposite association (Jacka et al., 2010; Melo et al., 2022). According to Berdin et al., (2021),

> The fact that many different dietary patterns have been linked to improved mental wellbeing reinforces the fact that individual components of the diet may be less important to mental health than overall dietary patterns high in plant foods and low in ultra-processed foods. (p. 1270)

The Mediterranean diet is one such pattern that is associated with less depression and cognitive impairment (Psaltopoulou et al., 2013).

Narrowing on the context of the present study, diet and lifestyle are believed to affect mental and psychological development in college students, specifically (Sánchez-Ojeda & Luna-Bertos, 2015). College students consuming diets with a higher Healthy Eating Index (HEI) reported significantly fewer days per month with poor mental health and a higher number of days per month feeling healthy and full of energy (Parsons et al., 2022).

Academic Outcomes. In addition to physical and mental health, dietary patterns also seem to affect academic performance. The school breakfast program may not have a significant impact on math and reading scores (Schanzenbach & Zaki, 2014). However, other studies demonstrated a connection between food consumption patterns and learning outcomes. Overall diet correlates with academic performance in college students (Valladares et al., 2016), and diet quality has also been found to be predictive of future academic performance (Florence et al., 2008). Qualitative research supports these findings as well. Walker (2020) conducted a

phenomenological investigation of the perceived detrimental impact of negative food choices on learning. Martin (2022) observed that students who eat a healthful breakfast or snack tended to have higher attention, motivation, engagement, participation, assignment completion rate, and grades.

Cognition. Dietary patterns have also been studied in the context of cognition. Despite one cohort study that indicated no relationship between midlife diet quality and subsequent risk of dementia (Akbaraly et al., 2019), a "growing body of evidence" indicates such a connection (Bonyadi et al., 2022, p. 1). The standard Western diet is associated with overall cognitive decline (Attuquayefio et al., 2017; Fotuhi et al., 2012; Gardener et al., 2015; Hendrie et al., 2016; Marx et al., 2021; Shakersain et al., 2016; Więckowska-Gacek et al., 2021). Specifically, the Western diet has been associated with increased dementia and psychiatric diseases (Melo et al., 2022) as well as decreased learning (Attuquayefio et al., 2017, Nyaradi et al., 2014; Więckowska-Gacek et al., 2021), memory (Attuquayefio et al., 2017; Więckowska-Gacek et al., 2021), visuospatial functioning (Gardener et al., 2015), and reaction time (Nyaradi et al., 2014).

In contrast, alternative diets appear to have positive impacts on cognition and brain health in general (Krivanek et al., 2021; Livingston et al., 2020; Rajaram et al., 2019). For example, the prudent diet, which limits several of the problematic components of the Western diet, is associated with less cognitive decline and higher visuospatial functioning (Gardener et al., 2015; Shakersain et al., 2016; Shakersain et al., 2018). Similar phenomena have been observed with other alternative dietary patterns, as described below.

Despite some evidence to the contrary (Livingston et al., 2020), the Mediterranean diet has generally demonstrated a lower risk of cognitive decline (Bernice, 2021; Gauci, 2022; Hosking et al., 2019; Krivanek et al., 2021; Loughrey et al., 2017; McEvoy et al., 2017; Psaltopoulou et al., 2013; Tangney et al., 2014; van den Brink et al., 2019). Specifically, the

Mediterranean diet is associated with improved executive function, language, verbal ability, short-term memory (Bernice, 2021), visuospatial functioning (Gardener et al., 2015), and episodic memory, but not improved working or semantic memory (Loughrey et al., 2017). Intervention trials also show positive outcomes on global cognition (Lee et al., 2015; Martínez-Lapiscina et al., 2013). Intervention studies reveal positive impacts on verbal fluency, processing speed, and working memory, but not episodic memory (Loughrey et al., 2017). Based on the whole sum of evidence, the World Health Organization recommends the Mediterranean diet, concluding that it is not harmful and has the potential to prevent cognitive decline (WHO, 2019).

The Dietary Approach to Stop Hypertension (DASH), originally developed for cardiometabolic benefits, has also been studied in the context of cognition (Krivanek et al., 2021). Like the Mediterranean diet, the DASH diet is also associated with decreased cognitive decline (Hosking et al., 2019; Krivanek et al., 2021; Tangney et al., 2014; van den Brink et al., 2019) and increased cognitive performance (Krivanek et al., 2021). Intervention studies also indicate a positive impact on global cognition and executive function (Krivanek et al., 2021; Lehtisalo et al., 2019).

The Mediterranean-DASH Intervention for Neurodegenerative Delay (MIND) diet is a hybrid diet specifically designed to have an impact on cognition (Krivanek et al., 2021). Like its predecessors, the MIND diet is also associated with decreased cognitive decline (Krivanek et al., 2021, van den Brink et al., 2019) and increased global cognition (Krivanek et al., 2021; McEvoy et al., 2017). Out of the Mediterranean, DASH, and MIND diets, the MIND diet is the only one associated with improved Stroop processing (Gauci, 2022). Based on evidence that the MIND diet is more effective at preventing cognitive decline over 12 years while requiring less strict adherence to be effective, Krivanek et al., (2021) suggest that the MIND diet may be the most effective diet for overall brain health.

Overall, there are mixed results regarding the impact of dietary patterns on verbal learning, specifically (Attuquayefio & Stevenson, 2015). Randomized controlled trials reveal that the Mediterranean diet appears to improve delayed recall (Loughrey et al., 2017; Valls-Pedret et al., 2015), but not immediate recall (Knight et al., 2015). The prudent diet appears to moderate the relationship between arterial stiffness and verbal learning, exacerbating the gap in verbal learning for low-vs. high arterial stiffness. This suggests that the prudent style diet may only provide preventative benefits that do not persist once arterial stiffness has already developed (Gauci, 2022). Although not a dietary pattern per se, a higher glycemic index has a demonstrated causal connection with decreased verbal learning through a strong experimental design (Sanchez-Aguadero et al., 2020). This finding, and the aforementioned connections in the literature, suggest that food processing level may be another classification technique with connections to verbal learning.

Food Processing Level Outcomes

Like glycemic index, food processing level is not a dietary pattern in the strict sense, but a broad way to classify or characterize the quality of any food item. Several outcomes of food processing level will be explored in the review, beginning with those related to physical health.

Physical Health. There are many demonstrated connections between eating processed foods and poor health outcomes. Ultra-processed food consumption is associated with a 20%-80% increased risk of non-communicable disease (Lane et al., 2021). In adults, more frequent consumption of ultra-processed food is associated with increased abdominal obesity (Lane et al., 2021; Martinez-Perez et al., 2021; Pagliai et al., 2021), breast cancer (Lane et al., 2021), cancer overall (Elizabeth et al., 2020; Fiolet et al., 2018; Lane et al., 2021), cardiometabolic dysfunction (Askari et al., 2020; Elizabeth et al., 2020; Lane et al., 2021), cardiovascular disease (de Miranda et al., 2021; Elizabeth et al., 2020; Lane et al., 2021; Pagliai et al., 2021; Srour et al., 2019; Yang

et al., 2020; Zhang et al., 2021), cerebrovascular disease (Pagliai et al., 2021; Srour et al., 2019), cholesterol (Martinez-Perez et al., 2021), creatinine (Martinez-Perez et al., 2021), dyspepsia (Lane et al., 2021), frailty (Elizabeth et al., 2020; Lane et al., 2021), HbA1c (Martinez-Perez et al., 2021), irritable bowel syndrome (Elizabeth et al., 2020; Lane et al., 2021), metabolic syndrome (de Miranda et al., 2021; Lane et al., 2021; Martínez Steele et al., 2019; Pagliai et al., 2021; Steel et al., 2019), overweight (Askari et al., 2020; Capra, 2022; Elizabeth et al., 2020; Juul et al., 2018; Lam & Adams, 2017; Lane et al., 2021; Martinez-Perez et al., 2021; Pagliai et al., 2021), obesity (Askari et al., 2020; Beslay et al., 2020; Costa et al., 2018; Elizabeth et al., 2020; Juul et al., 2018; Lane et al., 2021; Monteiro, Moubarac et al., 2018; Pagliai et al., 2021), type-2 diabetes (Elizabeth et al., 2020; Srour et al., 2019), and all-cause mortality (de Miranda et al., 2021; Elizabeth et al., 2020; Lane et al., 2021; Pagliai et al., 2021; Rico-Campà et al., 2019; Schnabel et al., 2019). Five servings of ultra-processed food per day increases the risk of all-cause mortality by 62%, with each additional serving raising the risk by 18% (Rico-Campà et al., 2019).

The physical health effects of ultra-processed food are more clearly demonstrated in adults than children (de Miranda et al., 2021), but all age groups appear to be impacted. Consumption of ultra-processed food is associated with increased asthma (Elizabeth et al., 2020), cardiometabolic risks (Askari et al., 2020; Costa et al., 2021; Elizabeth et al., 2020), metabolic syndrome (Lane et al., 2021), dyslipidemia (Lane et al., 2021), and obesity (Askari et al., 2020; Costa et al., 2021) in children and wheezing in adolescents (Lane et al., 2021). In one low-income community, children with the highest levels of ultra-processed food consumption at age 3 had significantly higher cholesterol and triglycerides at age 6 (Leffa et al., 2020). In a study of college students, fast food consumption (fried food and sweet snacks to a lesser degree) was the greatest risk factor for physical health (Lanuza et al., 2022). On the other hand, home-cooked

meals that tend to include less ultra-processed food (Monteiro, Cannon, Levy, et al., 2019), are a protective factor for all domains of quality of life, including physical, psychological, social, and environmental (Lanuza et al., 2022).

It has been hypothesized that ultra-processed food consumption is not just a coincidence but a causal factor behind chronic diseases such as cardiovascular disease, diabetes, and the global obesity epidemic (Juul et al., 2022; Elizabeth et al., 2020; Lane et al., 2021; Lustig, 2017; Pagliai et al., 2021; Pfreundschuh, 2022). This claim of causation is most clearly established for obesity. In a randomized crossover trial, participants gained weight on an ultra-processed diet and lost weight on a minimally processed diet, despite matching for calories and macronutrients (Hall et al., 2019). There seems to be a dose-dependent effect, such that a 10% increase in ultra-processed food is associated with a 9% increase in the incidence of obesity, after adjusting for age, alcohol consumption, calorie consumption, education level, marital status, physical activity, sex, and smoking status (Beslay et al., 2020). A similar dose-dependent effect is evident for cardiovascular disease, such that each 5% increase in ultra-processed food is associated with 0.14 points lower cardiovascular health score (Zhang et al., 2021).

Not all of the evidence suggests a straightforward relationship between the level of food processing and physical health outcomes. Lanuza et al. (2022) found that two or more portions of whole food per day were not a protective factor for any domain of quality of life, and Hall et al. (2019) found no significant difference in glucose tolerance between processed and unprocessed meals. In one study, ultra-processed food consumption was not associated with BMI, waist circumference, and obesity for men, despite significant positive associations for women (Sung et al., 2021).

The associations between consumption of processed foods and outcomes can also differ depending on the classification system used. Martinez-Perez et al. (2021) examined twelve

outcome variables with four classification systems. Ten of the 12 variables demonstrated inconsistent results that were generally a mixture of significant and nonsignificant results *p* values. The association between food processing level and HDL was negative when using the Nova classification system, but positive when using the other three systems (Martinez-Perez et al., 2021). The Nova finding would be consistent with the results of Pagliani et al (2021), who also found a negative relationship with HDL.

Mental Health. In addition to physical health outcomes, food processing level also has demonstrated relationships to mental health outcomes. Consumption of ultra-processed food is associated with increased symptoms of mental illness (Jacka et al., 2010), and this relationship persists in adolescents after controlling for socioeconomic status, alcohol, and tobacco use, physical activity, sedentary lifestyle, living with parents, eating with parents, number of close friends, relationships with parents and peers, self-perceived body image, and bullying victimization (Mesas et al., 2022). In addition to general mental health symptoms, ultra-processed food consumption is also associated with increased anxiety (Coletro et al., 2022) and depression (Adjibade et al., 2019; Coletro et al., 2022; Elizabeth et al., 2020; Lane et al., 2021; Pagliai et al., 2021). These findings may appear incongruent with the positive emotions felt when consuming a processed meal. However, in a study of college students, Cummings et al. (2022) found that the temporary increase in positive emotions and reduction in negative emotions from eating ultra-processed foods last between one and three hours, but do not persist beyond that period.

Academic Outcomes. There are fewer studies on the connection between consumption of processed food and academic outcomes. Blum et al. (2022) suggested that the removal of processed foods would result in higher academic performance. Quasi-experimental studies have

provided evidence in support of that hypothesis (Anderson et al., 2018; Belot & James, 2011; Hollar et al., 2010), but no true experiments have demonstrated causation.

Cognition. The literature has mixed results regarding the effects of consuming processed foods on cognition (Gauci, 2022). Some authors indicate that eating processed food is associated with poor cognition (Torres et al., 2012), faster cognitive decline (Gonçalves et al., 2023; Ozawa et al., 2017), and increased dementia (Melo et al., 2022). In an eight-year study of over 10,000 participants, Gonçalves et al. (2023) found that those in the upper three quartiles of ultra-processed food consumption had a 28% faster decline in global cognition, compared to those in the first quartile.

Some authors only found significant results for particular sub-categories of ultra-processed food and cognition, including verbal fluency. Cardoso et al. (2022) found a significant negative relationship with semantic fluency but not overall cognition. Similarly, Weinstein et al. (2023) found no overall relationship with cognitive decline. However, they found significant negative relationships between global cognition and executive functioning and ultra-processed meat, oils, and spreads. The relationships between ultra-processed dairy consumption and phonemic and semantic fluency were only significant for those with a BMI of 30 or greater (Weinstein et al., 2023). In the college context, Pilato et al. (2020) found that fast food consumption correlates with lower executive functioning in resident students and lower visual memory in commuters. Akbaraly et al. (2009) found significant inverse relationships between consumption of processed foods and vocabulary, phonemic fluency, and semantic fluency after controlling for behavior, demographic, and health factors. These results suggest that an experimental test of food processing level may reveal a significant connection to verbal fluency as well.

Regarding the connection between food processing level and verbal learning, the correlational literature on these topics does not suggest a significant causal connection. Akbaraly et al. (2009) asked participants to recall a list of 20 words to assess short-term verbal memory but did not find a significant relationship with the processing level of food consumed. Both Gonçalves et al., (2023) and Weinstein et al. (2023) used the CERAD cognitive battery to assess verbal memory but found no significant relationships between eating processed foods and memory. Cardoso et al. (2022) also used the CERAD to assess immediate and delayed recall. They found a negative trend between ultra-processed food consumption and total verbal learning score, but this trend did not reach significance ($p = 0.308$) (Cardoso et al., 2022). These studies use self-reported dietary data based on 24-hour recall, which may explain the inconsistency with previously discussed findings related to dietary components and patterns.

Mechanisms Behind Connections

Many mechanisms have been proposed to explain the connections between nutrition, physical health, mental health, cognition, and academic performance. Sorhaindo and Feinstein (2006) created a conceptual model indicating that socioeconomic status and lifestyle factors affect child nutrition, which affects a triad of physical development, cognition, and behavior. These three factors are assumed to have a combined influence on school life outcomes (Sorhaindo & Feinstein, 2006).

The specific mechanisms by which nutrition affects physical development and cognition can also be examined. It is clear that dietary macronutrient levels are involved in these mechanisms, and processed foods regularly include added sugar, salt, and trans-fat (Elizabeth et al., 2020). However, the mechanistic picture is more complex than macronutrient composition, because the associations between higher food processing level and poor health outcomes remain

significant even after controlling or adjusting for overall calories and macronutrient levels (Beslay et al., 2020; Costa et al., 2021; Hall et al., 2019).

The specific mechanisms leading from nutrient to physical development and cognition are “complex, multifaceted, interacting, and not restricted to any one biological pathway” (Marx et al., 2021, p. 1). Some of the major mechanisms proposed have involved epigenetics (IARC, 2021; Marx et al., 2021) and glucose control (Beilharz et al., 2015; Elizabeth et al., 2020; Francis & Stevenson, 2013; Iwata et al., 2011; Kanoski & Davidson, 2011; Kraegen & Cooney, 2008; Martinez-Perez et al., 2021; O'Keefe et al., 2008). Other mechanisms involve a lack of micronutrients needed for neurotransmitter function (Mesas et al., 2022) and an excess of carcinogens (Elizabeth et al., 2020) and other toxic substances (Berding et al., 2021; Leo & Campos, 2020; Pagliai et al., 2021; Uribarri et al., 2010; Zinöcker & Lindseth et al., 2018).

Several proposed mechanisms involve damage to specific parts of the body, such as the mitochondria (Marx et al., 2021), blood-brain barrier, (Beilharz et al., 2015; Francis & Stevenson, 2013; Kanoski & Davidson, 2011; Melo et al., 2022; Więckowska-Gacek et al., 2021), cardiovascular system (Beilharz et al., 2015; DeJarnett et al., 2014; Francis & Stevenson, 2013; Iwata et al., 2011; Kanoski & Davidson, 2011; Livingston et al., 2020), endocrine system (Berding et al., 2021; Buckley et al., 2019; Leo & Campos, 2020; Marx et al., 2021; Zinöcker & Lindseth et al., 2018), and increased permeability of intestines (Elizabeth et al., 2020).

One major proposed mechanism is that diet can impact the hippocampus and other areas of the brain that in turn affect cognition (Attuquayefio et al., 2017; Fanselow & Dong, 2010; Fotuhi et al., 2012; Jacka et al., 2015; Krivanek et al., 2021; Marx, 2021; Noble et al., 2017; Weinstein et al., 2023). A part of the limbic system, the hippocampus has a key function in mood, learning, and the formation of memories (Fanselow & Dong, 2010). Poor diet and chronic disease are associated with a smaller hippocampus, lower neuroplasticity, and increased

cognitive impairment (Fotuhi et al., 2012; Jacka et al., 2015). The Western diet has been found to harm the hippocampus (Attuquayefio et al., 2017; Marx et al., 2021). On the other hand, healthy diets may counteract this type of damage. Flavonoids appear to impact the cellular structure of the hippocampus in a way that slows cognitive decline (Kent, Charlton, Roodenrys, et al., 2017).

Two additional key mechanisms are the roles of diet in inflammation (Beilharz et al., 2015; Berding et al., 2021; Bernice, 2021; Francis & Stevenson, 2013; Gonçalves et al., 2023; IARC, 2021; Iwata et al., 2011; Kanoski & Davidson, 2011; Krivanek et al., 2021; Leo & Campos, 2020; Marx et al., 2021; Melo et al., 2022; Mesas et al., 2022; Więckowska-Gacek et al., 2021; Zinöcker & Lindseth et al., 2018) and oxidation (Beilharz et al., 2015; Berding et al., 2021; Bernice, 2021; Francis & Stevenson, 2013; IARC, 2021; Iwata et al., 2011; Kanoski & Davidson, 2011; Kent, Charlton, Roodenrys, et al., 2017; Leo & Campos, 2020; Marx et al., 2021; Zinöcker & Lindseth et al., 2018) on the brain and rest of the body. Red meat, processed meat, and ultra-processed food in general are high in proinflammatory compounds such as saturated fatty acid, high fructose corn syrup, oils, and additives and low in anti-inflammatory compounds like polyphenols, omega-3 fatty acids, and fiber (IARC, 2021; Mesas et al., 2022). The neurological benefits of the Mediterranean diet appear to involve the action of anti-inflammatory compounds from fruits and vegetables as well as polyphenols that can help ameliorate oxidation in the brain (Bernice, 2021; IARC, 2021). Anthocyanins have a positive effect through both mechanisms, neutralizing free radicals and protecting against inflammation in the brain; they also increase blood flow to the brain and start the formation of new neurons (Berding et al., 2021; Kent, Charlton, Roodenrys, et al., 2017).

Another proposed mechanism involves the gut microbiome and its impact on the brain (Berding et al., 2021; Elizabeth et al., 2020; Foster et al., 2013; IARC, 2021; Leo & Campos, 2020; Marx et al., 2021; Melo et al., 2022; Mesas et al., 2022; Noble et al., 2017; Pagliai et al.,

2021; Więckowska-Gacek et al., 2021; Wu et al., 2021; Zinöcker & Lindseth et al., 2018). There are trillions of bacteria, viruses, fungi, and other eukaryotes, representing hundreds of different species, which live in the human body, primarily in the intestines. Saturated fatty acids, sweeteners, emulsifiers, animal-based protein, and the Western diet in general are associated with a loss of overall microbiome diversity, a reduction in beneficial microbes, and an increase in pathogenic microbes. However, polyphenols, mono-unsaturated fatty acids, polyunsaturated fatty acids, fiber, prebiotics, plant-based protein, nuts, fruits, vegetables, fermented foods, the Mediterranean diet, and plant-based diets in general seem to cause the opposite effects on the gut (Berding et al., 2021).

These mechanisms indicate that factors that negatively impact the body also impact the mind. For example, it is likely not a coincidence that arterial stiffness correlates with decreased spatial working memory (Gauci, 2022) and high waist circumference is associated with increased dementia (Tang et al., 2021). One hypothesis is that ultra-processed food causes chronic diseases such as cardiovascular disease, diabetes, and obesity, which then negatively impact cognition and mental health (Elizabeth et al., 2020; Lane et al., 2021). Because these chronic diseases share risk factors with each other and mental health, some have proposed viewing mental health as one of the major four noncommunicable diseases (Lane et al., 2021). On the other hand, Krivanek (2021) provided evidence that consuming a heart-healthy diet results in increased brain volume and decreased inflammation, atrophy of the hippocampus, neuron death, and symptoms of Alzheimer’s Disease.

Marx et al. (2021) created a concept map for the mechanisms by which diet impacts mental health and obesity. Eight pathways influence depression: epigenetic change, the gut microbiome, hypothalamic-pituitary-adrenal axis dysfunction, inflammation, mitochondrial dysfunction, neurogenesis, oxidative stress, and tryptophan-kynurenine metabolism. These

pathways can have negative impacts on, and be negatively impacted by, obesity in a vicious cycle. A diet high in phytochemicals, vitamins, minerals, omega-3, polyunsaturated and monounsaturated fatty acids, and fiber can have positive effects on those pathways and decrease the risk of obesity. A Western diet low in phytochemicals, vitamins, and minerals and high in calories, high-glycemic index carbohydrates and sugars, trans fats, and saturated fats can have negative impacts on those pathways and increase the risk of obesity (Marx et al., 2021).

This mixture of mechanisms appears to damage cognition in synergistic ways. Więckowska-Gacek et al., (2021, p. 16) described a “vicious cycle” of diet-induced chronic disease and gut microbiome dysfunction combining to exacerbate inflammation and damage to the blood-brain barrier, allowing inflammatory compounds and cholesterol to negatively impact the brain. Based on this understanding, the authors stated that the Western diet is not simply a risk factor for cognitive impairment, but an initiating factor instead (Więckowska-Gacek et al., 2021).

Furthermore, these mechanisms appear to be exacerbated by the artificially engineered and addictive nature of certain foods (Cummings et al., 2022; Schulte et al., 2015). The intensive flavorings of ultra-processed foods and the lack of fiber or other satiety signals result in rapid eating speed and excessive amounts eaten overall (Elizabeth et al., 2020; Pagliai et al., 2021; Small & DiFeliceantonio, 2019; Wu et al., 2021; Zhang et al., 2021). The expectation of positive feelings upon consuming ultra-processed foods may contribute to the vicious cycle (Cummings et al., 2022).

Summary

The overarching theoretical framework for this study was postpositivism, an approach that assumes that objective cause-and-effect relationships can be discerned (Cresswell, 2018). Maslow’s theory (1943) described a hierarchy of five levels of needs: physiological, safety, love,

esteem, and self-actualization. It is implied that a self-actualization need like learning can only be met once physiological needs like nutrition are already met (Cassar 2022; Crandall et al., 2019; Filippello et al., 2019; Pokhrel & Chhetri, 2021). Due to the synergistic interactions between food components and foods themselves, a growing body of researchers recommends examining nutrition at higher levels of organization (Berding et al., 2021; Bernice, 2021; Kent, Charlton, Netzel & Fanning, 2017; Jacobs & Steffen, 2003; Messina et al., 2001; Tapsell et al., 2016).

Research on dietary components like sugar, sodium, and saturated fat and patterns like the Western and Mediterranean diets inform the dietary guidelines for Americans (USDA & HHS, 2020). Processed food has clear benefits as well as problematic components (Elizabeth et al., 2020; Weaver et al., 2014), and the Nova system (Monteiro et al., 2016) is the most widely used way to classify foods according to their processing status (Martinez-Perez et al., 2021). Verbal learning and fluency tests are simple, reliable, widely used methods to measure cognition (Cohen, 2020; Hawkins et al., 2004).

Regarding the nutritional context of the study, overall diet quality in the U.S. is poor (USDA & HHS, 2020). Ultra-processed food consumption is increasing on a global scale (Pagliai et al., 2021; Shim et al., 2021), disproportionally affecting those who are young, black, male, overweight, live in urban areas, or have limited income (Andrade, 2021; Marino et al., 2021; Shim et al., 2021; Wang et al., 2021). In the college setting, specifically, diet quality is poor (Parsons et al., 2022) and characterized by an elevated consumption of ultra-processed food (Juul et al., 2022). Food insecurity is one of several barriers to healthy eating in the college population (Blum et al., 2022; Willis, 2021).

A host of significant connections have been demonstrated between factors like nutrient components, specific foods, dietary patterns, and food processing level and outcomes like

physical health, mental health, academic performance, and cognition. Sugar, salt, and saturated fat associated with processed food are also associated with poor health and cognitive outcomes (Hooper et al., 2020; Na et al., 2022; USDA & HHS, 2020) whereas polyphenols found in non-Western dietary patterns like the Mediterranean diet appear to have the opposite effects (Gauci, 2022; Leber et al., 2022). Ultra-processed food consumption has a clearly demonstrated connection to poor physical health (Lane et al., 2021), but the research is not fully consistent regarding various aspects of cognition. The literature in general suggests a possible causal connection between a greater degree of food processing and decreased verbal learning and fluency, but prior to this study, these relationships had not yet been demonstrated with a true experiment. The following chapter will explain the chosen methodology to examine these relationships.

Chapter III. Methodology

Evidence suggests that access to and consumption of healthful food impacts growth (Wen et al., 2014), life expectancy (Murray et al., 2013), and learning (Liquori et al., 1998; Wang & Black, 2019). Nutrition is lacking in youth nationwide (Moore et al., 2017), but this problem can be particularly felt in minority communities (Adams et al., 2010, Adams et al., 2013, Wang & Black, 2019). Non-experimental evidence suggests that certain types of food may have a causal relationship with learning (Anderson et al., 2018; Belot & James, 2011; Doku et al., 2013; Hollar et al., 2010; Neumark-Sztainer et al., 1996; Peltzer & Pengpid, 2015), and researchers have begun to use strong experimental design to probe these relationships directly (Sanchez-Aguadero et al., 2020). The focus of this research was to answer the question: "What is the causal impact of processing level of food consumed (processed vs. minimally processed) and postprandial time (30 minutes vs. 90 minutes) on verbal fluency and verbal learning?"

This study determined the causal impact of processing level of food consumed on verbal learning and fluency using a repeated-measures quantitative experiment. The level of food processing and postprandial time served as the independent variables, whereas verbal learning and fluency were the dependent variables. Performing the experiment with the breakfast of consenting adult college students avoided the ethical concerns of working with a "protected class" like children (Suter, 2012, p. 100). Similarly, the choice to limit treatment to two meals total, while maintaining the rest of the students' meals unmanipulated, was intended to minimize risks to participants. This study avoided the tendency toward reductionism by focusing on major categories of food items (minimally processed vs. ultra-processed).

Research Design

This study used quantitative methods. Quantitative methods were appropriate because they are the only methods that can provide effective evidence of causation (Johnson &

Christensen, 2019, p. 35). In an experimental design, random assignment and controlled conditions allow the researcher to limit the interference of potentially confounding variables (Suter, 2012). The design was a laboratory-type experiment (Johnson & Christensen, 2019, p. 305) with a 2 x 2 repeated-measures design for each outcome variable (Johnson & Christensen, 2019, p. 331).

In a repeated-measures quantitative design, participants act as their own controls, experiencing each of the levels of treatment (Johnson & Christensen, 2019, p. 332). This design aligned with the methodology of Sanchez-Aguadero et al. (2020), who performed a similar study by investigating the causal impact of glycemic index on cognitive measures. Repeated-measures designs also allow for a smaller sample size (Johnson & Christensen, 2019, p. 332), ameliorating a limitation with the practicality of running such a study. Finally, the fact that individuals serve as their own controls in repeated-measures design minimizes variance in the data. The repeated-measures methodology is a strong experimental research design that uses counterbalancing to control for threats to internal validity (Johnson & Christensen, 2019, p. 321). To accomplish counterbalancing, participants were randomly assigned into one of four possible sets, as shown in Table 1 (Johnson & Christensen, 2019, p. 315).

Table 1

Counterbalanced Sequence of Assessment Forms

Set	First Test	Second Test	Third Test	Fourth Test
A	4	1	3	2
B	1	2	4	3
C	2	3	1	4
D	3	4	2	1

Note. Rey Auditory-Verbal Learning Test (RAVLT) form numbers correspond to those detailed in Hawkins, et al. (2004). Phonemic fluency forms numbers correspond to FAS, CFL, BHR, and PRW, respectively (Benton et al., 1994; Delis et al., 2001; Strauss et al., 2006). Category fluency form numbers correspond to animals, cities and towns, fruits and vegetables, and musical instruments, respectively (Cohen, 2020; Cunje et al., 2007).

The independent variables were manipulated via the “type technique” (Johnson & Christensen, 2019, p. 307). The two independent variables in this study were postprandial time and the Nova classification of ultra-processed vs. minimally processed foods (Monteiro et al., 2017). The choice of these classifications was based on concepts from Anderson et al. (2018), Belot and James (2011), Bowen et al. (2018), Liquori et al. (2018), and Sanchez-Aguadero et al. (2020).

The composition of each meal was decided through a multi-step procedure. First, foods were chosen based on the ability to provide minimally processed vs. ultra-processed alternatives, while maximizing relevance to traditional breakfast foods. Ultra-processed versions shared at least one key ingredient with their corresponding minimally processed versions. However, by definition, ultra-processed foods also include additional ingredients such as added salt, sugar, oil, and preservatives (Monteiro et al., 2017, pp. 9-10). The minimally processed breakfast was composed of whole-wheat crackers, minimally processed

blueberry jelly, and orange slices. The ultra-processed breakfast was composed of blueberry toaster pastries and ultra-processed orange juice.

Energy composition in kilocalories and grams of lipid, carbohydrate, and protein were calculated for each food, starting with the suggested serving size for each food item. The composition of each meal was then adjusted to standardize kilocalories for each corresponding item (Table 2). As previously performed by Hall et al., (2019), the matching of calories was a way to standardize the amount of food offered, helping to rule out energy content as a competing hypothesis (Pagliai et al., 2021).

Table 2

Energy and Macronutrient Composition in Individual Food Items

Group	Food	Amount	Kilocalories	Lipid (g)	Carbohydrate (g)	Protein (g)
Minimally Processed	Orange	118 ml	42	0	11	1
	Cracker	3 crackers	300	2	69	9
	Jelly	118 ml	61	1	15	0
	Total		403	2	95	10
Ultra-processed	Orange Juice	177.4 ml	40	0	11	0
	Toaster Pastry	2 pastries	370	9	70	3
	Total		410	9	81	3

Breakfast alone was manipulated once per week for two weeks total, keeping the rest of the participants' meals unchanged. Two trials were necessary to accommodate each of the two levels of breakfast type. The choice to use short-term dietary changes (i.e., two meals total), as opposed to more extensive interventions, was intended to alleviate ethical concerns regarding physical, mental, and emotional risks to participants (Suter, 2012, p. 97).

Setting and Sample

The sample was drawn from consenting college students in a small English-speaking university in central Pennsylvania, ages 18-25 (Hochberg & Konner, 2020). I contacted school

officials to seek permission to conduct the experiment on school grounds and disseminate the call for research. The required sample size for a two-way ANOVA was calculated in G*Power to recognize a change of at least 1 unit in verbal learning score with an alpha of 0.05, power of 0.80, medium effect size (*f*=.25), standard deviation of 2.2, and four groups (Faul et al., 2007; Sanchez-Aguadero et al., 2020). Any sample size above 30 would have produced reasonably accurate *p* values in two-way repeated-measures ANOVA, even if the normality assumption was violated (Green & Salkind, 2017, p. 179).

The sample was a voluntary response sample. Criteria for inclusion included: (1) age 18-25, (2) status as a college student, and (2) willingness and ability to consume the foods selected. To avoid additional complications and minimize variability in data, additional exclusion criteria included: known food allergies or sensitivities, celiac disease, pregnancy, lactose intolerance, low-calorie and/or low-sodium diets, and diagnosis and/or treatment of cardiovascular events, diabetes mellitus, dyslipidemia, and hypertension (Sanchez-Aguadero et al., 2020).

Instrumentation

Learning is a latent variable that cannot be measured directly; therefore, it was necessary to choose a specific manifest variable in its place (Muijs, 2010). A pre-validated measurement instrument was preferred to measure such a construct (Johnson & Christensen, 2019, p. 173). Due to their previously demonstrated sensitivity to a different food classification system (Akbaraly et al., 2009; Cardoso et al., 2022; Sanchez-Aguadero et al., 2020; Weinstein et al., 2023), verbal memory and verbal fluency were chosen as the neuropsychological measurement variables in this study. Data were collected from four similar, but not identical, versions of the Rey Auditory-Verbal Learning Test, Semantic Fluency Test, and Phonemic Fluency Test (Hawkins et al., 2004; Strauss et al., 2006). Alternate versions of the RAVLT were sourced from

Lezak (1983) and Shapiro and Harrison (1990). Phonemic fluency forms included FAS, CFL, BHR, and PRW (Benton et al., 1994; Delis et al., 2001; Strauss et al., 2006). Category fluency forms included animals, cities and towns, fruits and vegetables, and musical instruments (Cohen, 2020; Cunje et al., 2007).

Data Collection Procedures

The RAVLT, semantic fluency test, and phonemic fluency test were conducted according to the procedures detailed in Chapter II. The total number of words recalled during the five learning trials was used as the primary outcome variable for the RAVLT. This total recall measure was preferable over individual learning trial scores due to increased reliability (Hawkins et al., 2004, p. 105). However, separate analyses were also run on immediate memory, retention, delayed recall, recognition, interference list score, proactive interference, and retroactive interference. Similarly, the total words produced were the primary outcome variable for verbal fluency tests, but similar analyses were run on perseverations, intrusions, switches, total cluster size, and average cluster size. Details on the distinctions between these measures are available in the definition of terms in Chapter I.

The tests were conducted 30 and 90 minutes after starting breakfast. This timing was intended to allow for the detection of potentially varying results after digestion, absorption, and subsequent biological effects of the meal (Sanchez-Aguadero et al., 2020). Procedural directions assessment items were standardized using the Flexiquiz online quiz platform. Participant responses were collected, organized, and stored using the same platform. This use of technology allowed for the secure collection and storage of data, as well as ensuring accuracy of data coding.

Handling of the Data

I was blinded to the individual participants' responses. Upon agreeing to the study, participants were assigned a numerical code to be used as their usernames in the video platform. I provided scripted directions with the participant's username. The key to identifying participants based on usernames was kept in a locked box throughout the duration of data collection. Responses, stored securely on the password-protected Flexiquiz platform, were identifiable only through the key. Once the study was complete, I destroyed the key matching the participant names to their usernames. A trained assistant, with no knowledge of which username corresponds to which participant, scored the responses and entered the data in Microsoft Excel without entering the participants' names. The Microsoft Excel file was saved as an encrypted file on a password-protected cloud storage system, Google Drive. Three years after completion of the study, the Excel file and the digital responses on the Flexiquiz platform will be deleted.

Data Analysis

With two independent variables and two levels of each independent variable, data analysis was a comparison of means via two-way repeated-measures ANOVA. This technique allowed for statistical comparison of results within both independent variables, as well as potential interactions between the variables. In this analysis, processing level of food consumed and postprandial time were within-subjects categorical variables (Green & Salkind, 2017, p. 176).

The Rey Auditory-Verbal Learning Test produced quantitative data with an initial score range from zero to 15. Total recall, the sum of the first five learning trials, had a score range from zero to 75. Proactive interference had a range of -15 to 15, whereas retroactive interference had a range of -100 to 100. Verbal fluency data were also quantitative with a minimum score of zero and no upper limit.

Missing data were first assessed and then replaced through multiple imputation within SPSS. This method was designed to ameliorate missing data in situations where a nontrivial amount of data (e.g., > 5%) is missing. This process used all the available data to simulate the most likely values for the missing data points. Ten imputations were run with the Markov Chain Monte Carlo method, culminating in replacement data equal to the average of the ten simulated values. In situations involving missing data, multiple imputation has been recommended as the optimal way to generate the most valid estimates of the true parameters and therefore perform the best overall hypothesis testing based on the data available (Newgard & Haukoos, 2007).

The normality of data was assessed with visual inspection of box plots, histograms, Kolmogorov-Smirnov tests, and Shapiro-Wilk tests (Green & Salkind, 2017, p. 262). Analyses were repeated for total recall, immediate memory, retention, delayed recall, recognition, interference list score, proactive interference, retroactive interference, total verbal fluency scores, perseverations, intrusions, switches, total cluster size, and average cluster size. These measures are described more fully in the definition of terms in Chapter I.

ANOVA Test

Each specific outcome variable was analyzed through Analysis of Variance. Because the main effects and interaction effects had one degree of freedom in the numerator, a standard univariate test was used (Green & Salkind, 2017, p. 177). Main effects of estimated marginal means were compared with Tukey’s Least Square Difference (LSD) approach. The three assumptions of the standard univariate test were: normal distribution of the dependent variable within each combination of independent variables, sphericity, and random sampling of independent cases (Green & Salkind, 2017, pp. 179-180).

Certain assumptions had a greater influence on the validity of the study than others. Even if the data were not normally distributed, the first assumption was compensated for by having a large enough sample (Green & Salkind, 2017, p. 179). The second assumption, sphericity, assumed that the variances within each set of compared differences were equal. This assumption is only relevant when the main effect or interaction has more than one degree of freedom (Green & Salkind, 2017, p. 179). Because this study only had two levels within each factor, this assumption was irrelevant. Unless controlled for in the procedure, a treatment diffusion effect could have otherwise violated the third assumption of independent cases.

Follow-Up Tests

For a significant main effect with no significant interaction effect in the standard univariate test, follow-up pairwise comparison tests would normally be given if a factor had more than two levels (Green & Salkind, 2017, p. 177). However, these tests were not necessary in this study because each factor had only two levels. Each main effect only consisted of one set of difference scores, so further follow-up tests of pairwise comparisons were not necessary (Green & Salkind, 2017, p. 178)

Simple main effects tests were required for significant interactions between postprandial time and food processing level (Green & Salkind, 2017, p. 177). These tests allowed the interaction effect to be teased apart from any main effects. Simple main effects were evaluated for food processing level within postprandial time and postprandial time within food processing level. The simple main effects for food processing level within postprandial time evaluated the mean differences in the dependent variable between levels of food processing for each level of postprandial time. The simple main effects for postprandial time within food processing level evaluated the mean differences in the dependent variable between levels of postprandial time for each level of food processing (Green & Salkind, 2017,

p. 179). Because each simple main effect had two levels, paired-samples *t*-tests were used for this purpose (Green & Salkind, 2017, p. 182). These tests were controlled for familywise error rate using Holm's sequential Bonferroni procedure. Out of the two comparisons, the one with the smallest *p* value was compared to $\alpha = .05/2 = .025$. The next lowest *p* value was compared to $\alpha = .05/1 = .05$ (Green & Salkind, 2017, p. 183).

The effect sizes for the main effects and interaction effects were calculated as partial eta square. This was calculated as follows:

$$\text{Partial } \eta^2_{\textit{Main or Interaction}} = \frac{\text{Sum of Squares}_{\textit{Main or Interaction}}}{\text{Sum of Squares}_{\textit{Main or Interaction}} + \text{Sum of Squares}_{\textit{Error}}}$$

Eta square ranges from zero to one, such that zero represents no relationship with the dependent variable, and one represents the strongest relationship possible (Green & Salkind, 2017, p. 180). However, eta square values of .01, .06, and .14 were considered to be small, medium, and large, respectively (Green & Salkind, 2017, p. 126). Data were displayed graphically using a profile plot (Green & Salkind, 2017, p. 184).

Internal Validity

According to Suter (2012), a study has internal validity "to the extent that the outcome can be explained by variation introduced by the treatment, and not an uncontrolled variable" (p. 191). Campbell and Stanley (1963) described five threats to internal validity, including extraneous events, instrumentation, mortality, regression, and selection (as cited in Suter, 2012, pp. 191-195). These threats were minimized through the repeated-measures experimental design because participants acted as their own controls (Johnson & Christensen, 2019, p. 332). However, a more detailed analysis of each threat will follow.

Extraneous events include outside history or maturation events that occur during the course of the study, changing results from the beginning to the end (Suter, 2012, p. 192). For

example, if a subgroup of participants ate the same meals during the washout period of the study, extraneous events may have easily confounded the results of the study, masking or altering the true impact of the independent variables. However, by randomly assigning a counterbalanced order of meals and forms, the impact of these extraneous events was minimized (Johnson & Christensen, 2019, p. 321).

Instrumentation was another potential threat to internal validity. This threat describes any source of bias related to the measurement of the dependent variable itself (Suter, 2012, p. 193). For example, participants may have performed better during subsequent trials, simply because they knew what to expect from the verbal learning test. Alternatively, participants may have developed a strategy for performing better on the test at some point during the study. Both of these possibilities are examples of ordering effects. Because practice effects have been found for verbal learning and fluency (Shapiro and Harrison, 1990; Strauss et al., 2006; Wilson et al., 2000), Hawkins et al. (2004) recommended counterbalanced administration when using multiple forms. Counterbalancing "averages out sequencing and order effects so that these problems are not present in the final, combined results" (Johnson & Christensen, 2019, p. 332).

Another potential instrumentation bias was a change in the instrument itself. By standardizing the presentation of the assessment with Flexiquiz and using validated and similar, yet not identical, versions of the test, these concerns were minimized. The four alternate tests used in this study produce similar scores (Cohen, 2020; Cunje et al., 2007; Shapiro & Harrison, 1990). These differences have been described as minor and not presenting concern for serial testing (Cunje et al., 2007; Hawkins et al., 2004).

Mortality was yet another potential threat to internal validity. This represents bias due to the attrition of participants during the study. Because this study was conducted over two

weeks, mortality would have become a problem if participants chose to not continue. Fortunately, attrition of a few subjects is not problematic; larger, systematic losses are the greater threat to validity (Suter, 2012, p. 194). Systematic losses were not a concern due to the random sequence of testing. However, proactively choosing a larger-than-required sample size was intended to account for the possibility of attrition. Regardless, all forty participants who were randomized to start the study also finished the study, eliminating this threat to internal validity.

The final two potential threats to internal validity were regression and selection. Regression is the phenomenon by which participants with extreme scores naturally tend to perform closer to the mean on subsequent tests (Suter, 2012, p. 194). This effect was minimized by counterbalancing, such that regression effects were spread across the four levels of treatment. Selection bias occurs when experimental and comparison groups are not equivalent (Suter, 2012, p. 195). Because participants served as their own controls in the repeated-measures design, this effect was eliminated.

In addition to five previously discussed threats to internal validity, additional threats may have been involved. The expectancy effect results when researcher bias influences the study, creating a self-fulfilling prophecy (Suter, 2012, p. 187). Although all researchers have bias, the impact of this bias was minimized through procedural controls. For example, test results were scored through a trained third party who was blinded to the meal associated with each test.

Unfortunately, participants could not be blinded to the type of meal they received and likely made inferences about what was being tested. Deception authorized in advance by the Institutional Review Board was used to minimize this effect; the informed consent form indicated that participants may not know all of the details of the study until the completion of

the study. While participants were informed of the general nature of the study, specific information regarding the variables studied was not shared upfront. Nevertheless, participants may have tried harder or otherwise performed atypically due to their awareness of different foods being tested. Treatment diffusion may have further exacerbated these concerns if participants communicated with each other, potentially impacting the results (Johnson & Christensen, 2019, p. 281). The randomized counterbalancing of the study sequence was intended to minimize the impact of these threats.

The repeated-measures design involved a final specific potential threat to validity, known as the carryover effect. For example, one might imagine that the consumption of one meal might, in some way, alter the performance in subsequent trials. This effect was minimized by having a one-week washout period between meals (Sanchez-Aguadero et al.; 2020), in addition to the counterbalancing technique (Johnson & Christensen, 2019, p. 315).

External Validity.

External validity is also known as generalizability. Random selection ensures that participants reflect the population that they were drawn from so that conclusions can be generalized to that population (Suter, 2012, p. 236). Johnson and Christensen (2019) wrote that "random samples are almost always more representative than nonrandom samples" (p. 240). However, due to practical issues, experiments are "rarely, if ever, based on random samples" (Johnson & Christensen, 2019, p. 255). The majority of experimental studies are done with convenience samples instead of random samples (Johnson & Christensen, 2019, p. 253). Therefore, even though random selection was sought at the host university, the selection method was ultimately a voluntary response sample.

In a broader sense, choosing 18–25-year-old students from a given institution limited generalizability to that institution's 18–25-year-old students; results may vary at other

universities. On an even larger scale, college students in general do not necessarily reflect the broader population. Peltzer and Pengpid (2015) commented on the fact that their data may not be generalizable due to the affluence of the college demographic. Nevertheless, because it would be impractical to randomly sample all learners, these types of delimitations invariably occur at some level.

Ethical Considerations and Informed Consent

The three overarching principles for ethical research are: "respect for persons (i.e., privacy and consent), concern for welfare (i.e., minimize harm and maximize reciprocity), and justice (i.e., equitable treatment and enhance inclusivity)" (Creswell & Poth, 2018, p.149). Respectful, professional relationships begin with informed consent. Informed consent from the participants was critical for the ethical integrity of this study (Creswell & Poth, 2018, p. 55).

Institutional Review Board (IRB) approval was obtained before any data were collected. The choice to study consenting adults, as opposed to children, was intended to help allay ethical concerns about working with a protected class (Suter, 2012, p. 100). Similarly, the choice to modify one meal per week, while leaving the rest of the participants' meals unmodified, was also intended to relieve potential ethical concerns regarding risks to participants (Suter, 2012, p. 97).

Although risks can never be fully eliminated, they can be managed appropriately. As a result, the knowledge gained from this study can help inform policies that may benefit the health and wellness of children and adults around the world. This potential benefit does not justify a hands-off approach when it comes to ethical concerns. Tracy (2013) encouraged researchers to "do no harm," rely on informed consent, and treat participants as "whole people rather than just subjects" (as cited in Merriam & Tisdell, 2016, p. 261).

This relational ethic is similar to Kant's categorical imperative, which could be summarized as treating people as ends themselves, rather than just means to an end (Tiles, 2000,

pp. 173-176). Creswell and Poth (2018) provided a host of practical suggestions for ensuring that research proceeds in an honest, respectful manner (p. 55). Nevertheless, it can be useful to have a counselor to provide advice on novel ethical matters that inevitably arise (Merriam & Tisdell, 2016, p. 265). My advisor and other members of my doctoral committee served effectively in this role.

Chapter Summary

This quantitative, laboratory-type experiment used a 2x2 repeated-measures design. Meals were provided to isolate the effect of food processing level. College students were sampled from a small, English-speaking university in Pennsylvania while maintaining sensitivity to several exclusion criteria. Results from the Rey Auditory-Verbal Learning Test and verbal fluency tests were assessed for normality and analyzed for main effects and interactions through ANOVA. Follow-up tests were conducted as necessary and effect sizes were calculated. Threats to validity were minimized through random assignment and counterbalancing within groups. A discussion of specific findings is included in Chapter IV.

Chapter IV. Findings

The purpose of this study was to answer the question: "What is the causal impact of processing level of food consumed (ultra-processed vs. minimally processed) and postprandial time (30 minutes vs. 90 minutes) on verbal fluency and learning?" Processing level of food consumed has two levels: minimally processed and ultra-processed. Postprandial time also has two levels: 30 minutes and 90 minutes. The dependent variables are verbal learning (hypotheses 1–3), phonemic fluency (hypotheses 4–6), and semantic fluency (hypotheses 7–9). The null hypotheses are:

$H1_{0:}$ There is no statistically significant relationship between processing level of food consumed and measures of verbal learning.

$H2_0$: There is no statistically significant relationship between postprandial time and measures of verbal learning.

$H3_0$: Regarding measures of verbal learning, there are no statistically significant interactions between postprandial time and processing level of food consumed.

$H4_{0:}$ There is no statistically significant relationship between processing level of food consumed and measures of phonemic fluency.

$H5_0$: There is no statistically significant relationship between postprandial time and measures of phonemic fluency.

$H6_0$: Regarding phonemic fluency, there are no statistically significant interactions between postprandial time and processing level of food consumed.

$H7_{0:}$ There is no statistically significant relationship between processing level of food consumed and measures of semantic fluency.

$H8_0$: There is no statistically significant relationship between postprandial time and measures of semantic fluency.

$H9_0$: Regarding semantic fluency, there are no statistically significant interactions between postprandial time and processing level of food consumed.

This chapter first describes the sample of participants, including a discussion of normality. Then, results for each dependent variable (verbal learning, phonemic fluency, and semantic fluency) are addressed separately. For each variable, specific measures related to the variable are defined. Then, each measure is analyzed serially. Descriptive information is shared, including mean, standard deviation, and box plots. Then, inferential statistics are shared, including repeated-measures Analysis of Variance (ANOVA), and paired-samples *t*-tests for any significant interactions.

Sample

The sample consisted of forty adult participants, composed of 23 women and 17 men. Table 3 reports the frequencies and percentages associated with select demographic characteristics. The most frequently occurring age group was 21 years ($n = 27$), followed by 22 years ($n = 5$), 18 years, ($n = 3$), 19 and 20 years ($n = 2$ for both), and 24 years ($n = 1$). The most frequently occurring year of university was junior ($n = 35$), followed by first-year students ($n = 3$) and sophomores ($n = 2$). No seniors or fifth-year students participated in the study.

Table 3

Selected Demographic Characteristics by Number and Percentage

Demographic	*n*	%
Sex	40	
Male	17	42.5
Female	23	57.5
Age (years)	40	
18	3	7.5
19	2	5.0
20	2	5.0
21	27	67.5
22	5	12.5
23	0	0.0
24	1	2.5
25	0	0.0
Year of University	40	
First Year	3	7.5
Sophomore	2	5.0
Junior	35	87.5
Senior	0	0.0
Fifth Year	0	0.0

Histograms of the data are available in Figures E1-E80 in Appendix E. Results of Kolmogorov-Smirnov and Shapiro-Wilk tests are displayed in Tables F1-F20 in Appendix F. One of the assumptions of repeated-measures ANOVA is a normal distribution. A non-normal distribution can reduce the power of the repeated-measures ANOVA (Green & Salkind, 2017, p. 179). However, even if data do not produce evidence of normality, the normality assumption can be compensated for by having a large enough sample size. Means become more stable with a sample size of at least 30 (Suter, 2012, p. 228). Any sample size above 30 can produce reasonably accurate p values in two-way repeated-measures ANOVA, even if the normality assumption is violated (Green & Salkind, 2017, p. 179). Therefore, due to the large sample size of 40 participants, parametric analysis was performed even when visual inspection of data or the Shapiro-Wilk test data did not provide evidence of normality.

Hypotheses 1–3: Verbal Learning Results

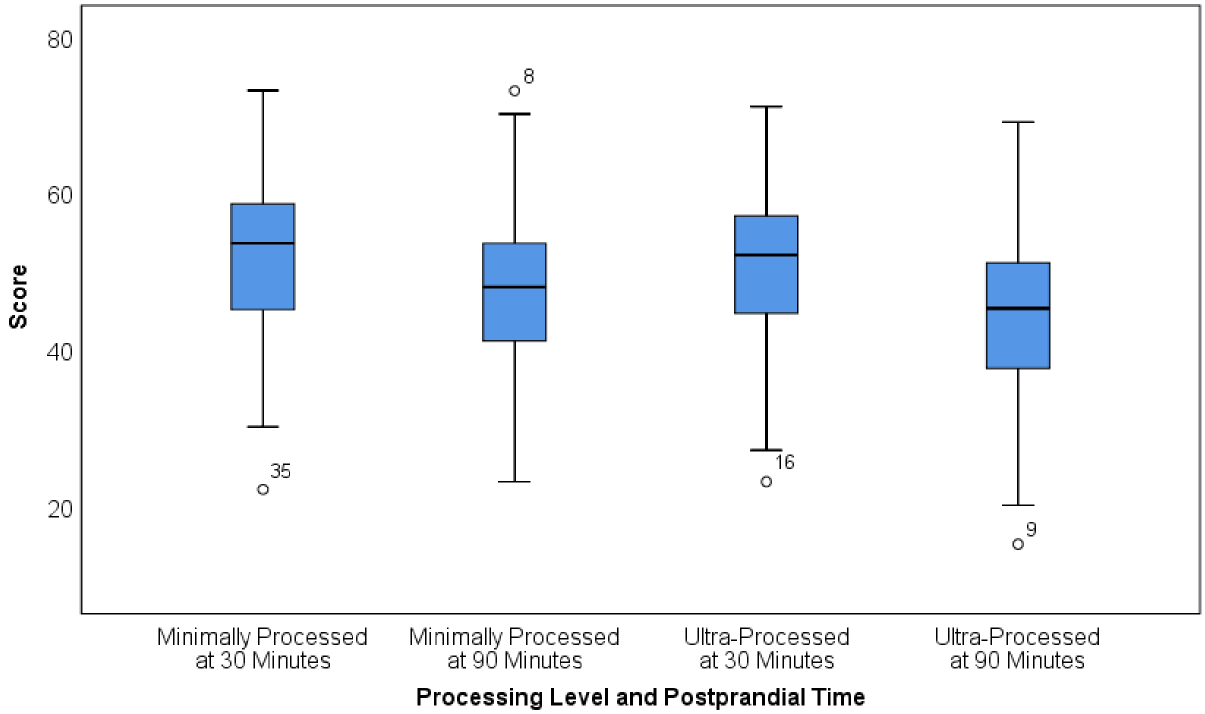
There are eight specific measures related to verbal learning. The primary measure of verbal learning is total recall, the sum of trials 1-5 in the Rey Auditory Verbal Learning Test (RAVLT). Immediate memory is the score on the first trial. Delayed recall is the score for the trial that follows a 20-minute delay. Recognition is the number of words correctly selected from a list that includes distractors. Interference list score is the score for the distractor trial. Retention is the score on the trial that follows the distractor trial. Proactive interference is the reduction in score on the distractor trial due to learning the initial list, calculated as the change in score from the first trial to the distractor trial. Retroactive interference is the percentage of words lost when comparing the score just before and just after the distractor trial.

Total Recall

The primary measure of verbal learning is total recall. Total recall is the sum of the words remembered in the initial five trials of the RAVLT. Figure 2 displays boxplots of the total recall data.

Figure 2

Box Plots of Verbal Learning Total Recall



Four outliers were present in the data. The highest mean total recall score was in the minimally processed group at 30 minutes (*M* = 51.27, *SD* = 10.57), followed by the ultra-processed group at 30 minutes (*M* = 49.98, *SD* = 10.68), followed by the minimally processed group at 90 minutes (*M* = 47.44, *SD* = 11.30), followed by the ultra-processed group at 90 minutes (*M* = 44.53, *SD* = 12.32).

A two-way within-subjects Analysis of Variance was conducted to evaluate the effect of processing level and postprandial time on total recall. The dependent variable was a total recall score on a scale from 0 to 75. The within-subjects factors were postprandial time with two levels (30 minutes and 90 minutes) and processing level with two levels (minimally processed and ultra-processed). The resulting test results are available in Table 4.

Table 4

ANOVA Results for Verbal Learning Total Recall

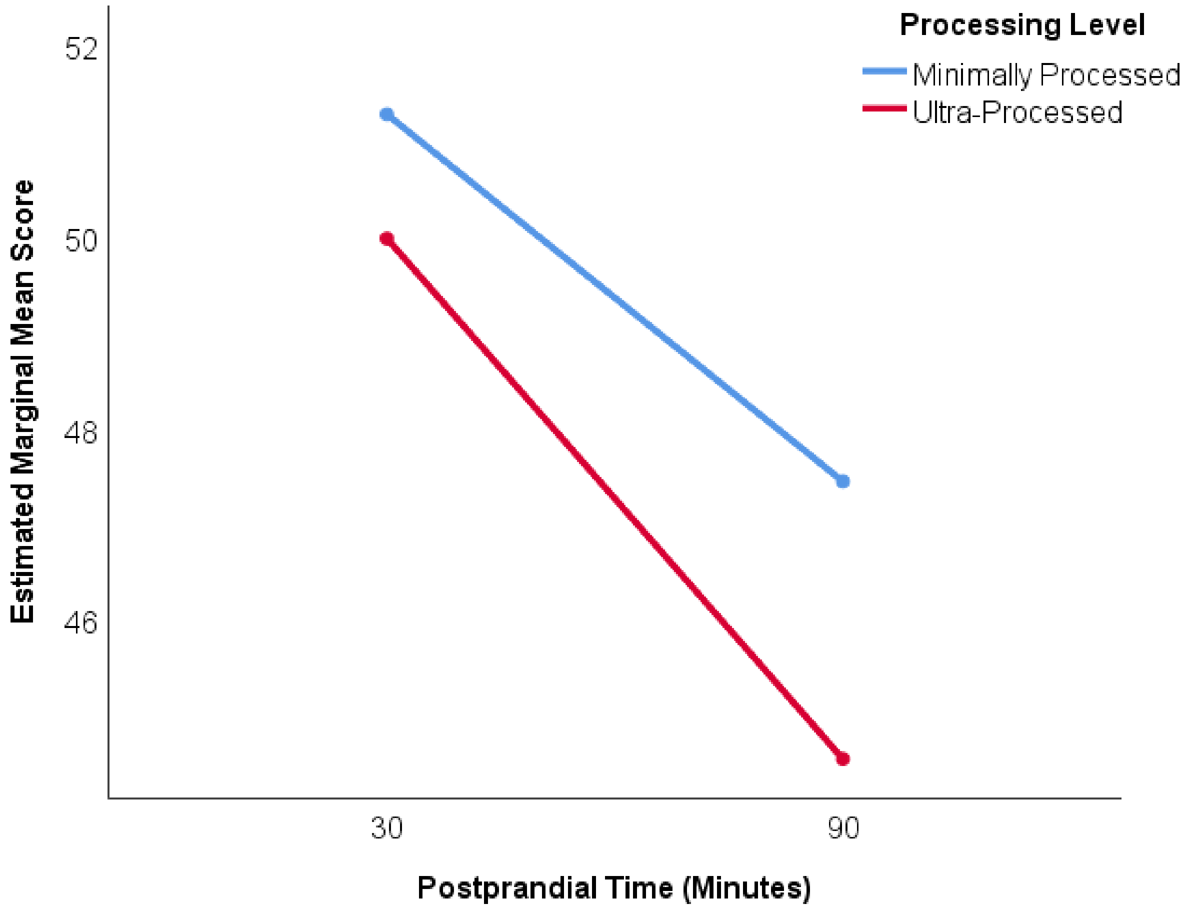
Source	Sum of Squares	*df*	Mean Square	*F*	*p*	η^2
P	176.46	1	176.46	4.06^{*}	.05	.09
Error (P)	1696.65	39	43.50			
T	861.83	1	861.83	17.36^{**}	<.01	.31
Error (T)	1936.18	39	49.65			
P * T	25.73	1	25.73	.37	.55	.01
Error (P * T)	2741.27	39	70.29			

Note. ANOVA = Analysis of Variance; P = Processing Level; T = Postprandial Time.
$^{*}p < .05$. $^{**}p < .01$

The interaction between postprandial time and processing level was found to be nonsignificant, $F(1, 39) = .37$, $p = .55$, partial $\eta^2 = .01$. Therefore, follow-up tests for simple main effects were not conducted. The univariate test associated with the processing level main effect was significant, $F(1, 39) = 4.06$, $p = .05$, partial $\eta^2 = .09$. The univariate test associated with the postprandial time main effect was also significant, $F(1, 39) = 17.36$, $p < .01$, partial $\eta^2 = .31$. In summary, total recall was significantly greater in the minimally processed group, compared to the processed group, as well as at 30 minutes, compared to 90 minutes. The effect sizes indicated that processing level and postprandial time accounted for 9% and 31% of the variance in verbal learning, respectively. These effect sizes were considered medium and large, respectively (Green & Salkind, 2017, p. 126). Both effects are visible in Figure 3.

Figure 3

Profile Plots of Verbal Learning Total Recall

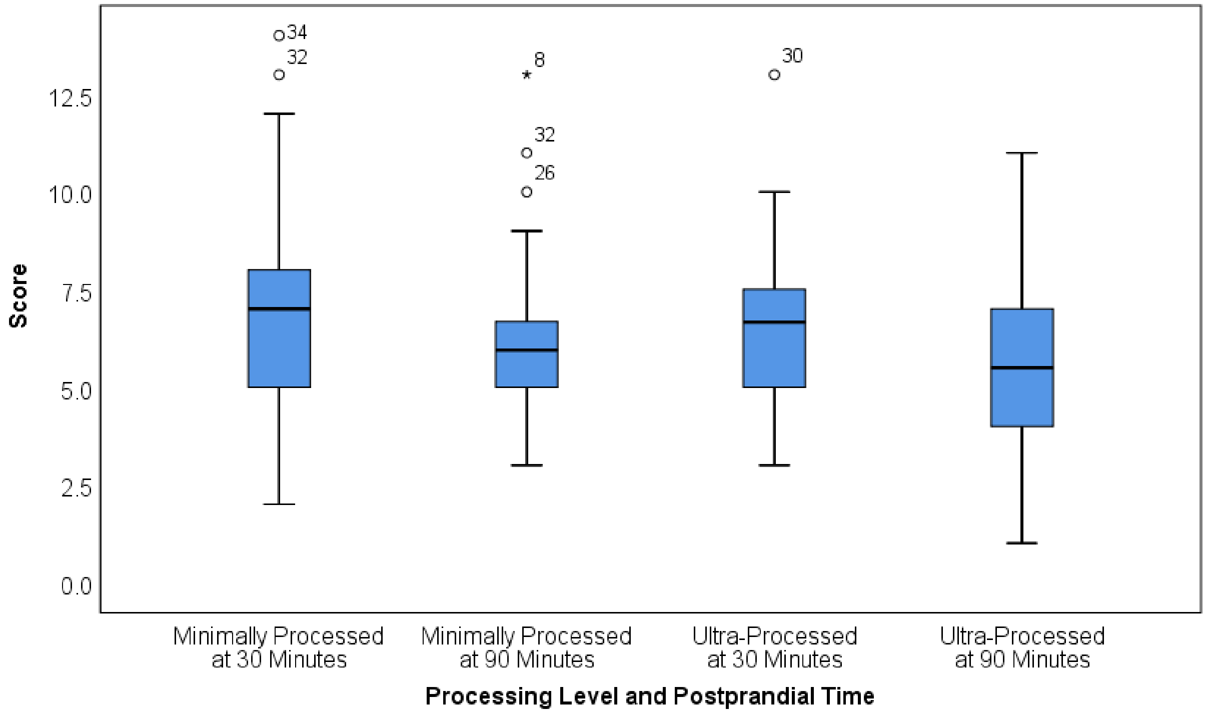


Immediate Memory

One of the additional measures of verbal learning is immediate memory. Immediate memory is the number of words remembered in the first trial of the RAVLT. Figure 4 displays boxplots of the immediate memory data.

Figure 4

Box Plots of Verbal Learning Immediate Memory



Six outliers were present in the data. The highest mean immediate memory score was in the minimally processed group at 30 minutes (*M* = 6.98, *SD* = 2.54), followed by the ultra-processed group at 30 minutes (*M* = 6.58, *SD* =2.02), followed by the minimally processed group at 90 minutes (*M* = 6.08, *SD* = 2.03), followed by the ultra-processed group at 90 minutes (*M* = 5.53, *SD* = 2.03).

A two-way within-subjects Analysis of Variance was conducted to evaluate the effect of processing level and postprandial time on immediate memory. The dependent variable was an immediate memory score on a scale from 0 to 15. The within-subjects factors were postprandial time with two levels (30 minutes and 90 minutes) and processing level with two levels (minimally processed and ultra-processed). The resulting test results are available in Table 5.

Table 5

ANOVA Results for Verbal Learning Immediate Memory

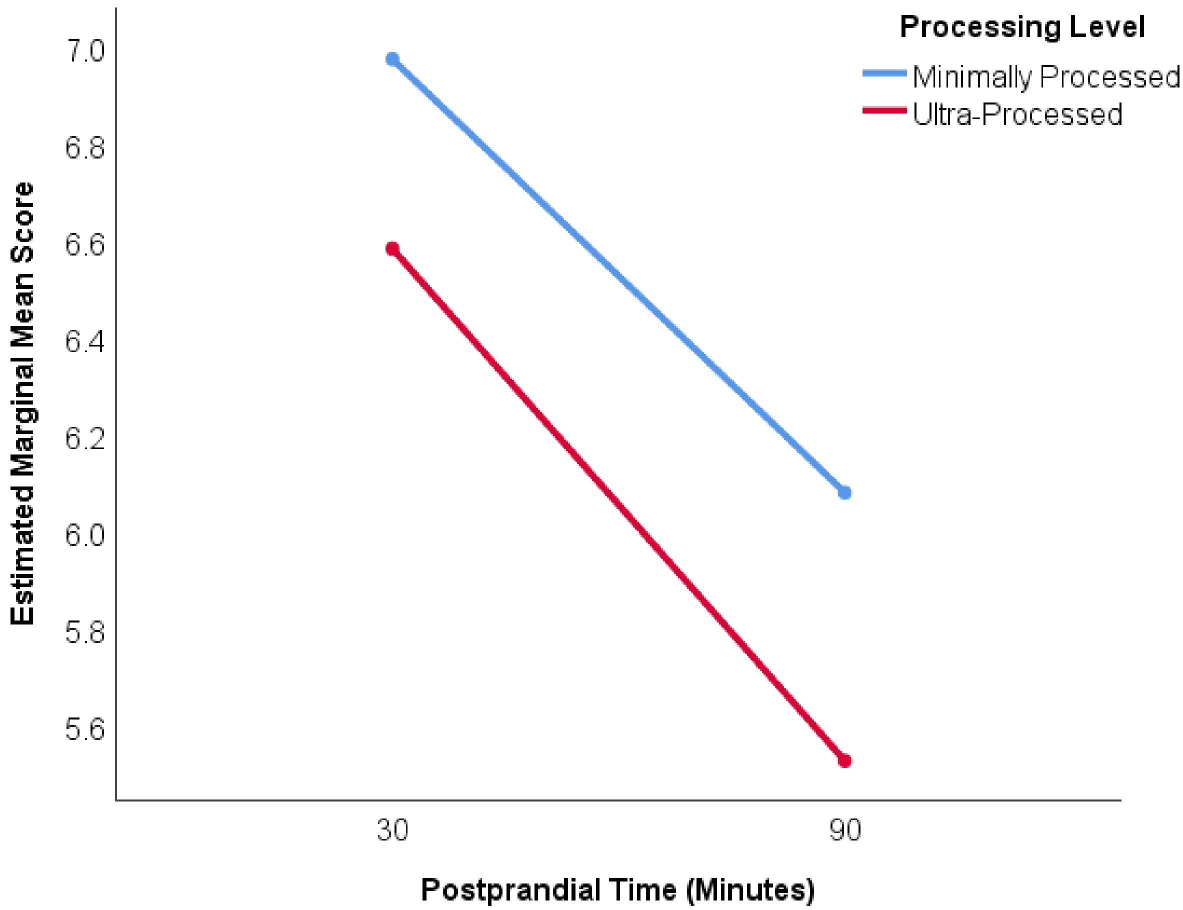
Source	Sum of Squares	*df*	Mean Square	*F*	*p*	η^2
P	8.95	1	8.95	1.95	.17	.05
Error (P)	178.78	39	4.58			
T	38.19	1	38.19	16.93**	<.01	.30
Error (T)	87.97	39	2.26			
P * T	.26	1	.26	0.14	.71	<.01
Error (P * T)	74.38	39	1.91			

Note. ANOVA = Analysis of Variance; P = Processing Level; T = Postprandial Time.
$^{*}p < .05$. $^{**}p < .01$

The interaction between postprandial time and processing level was found to be nonsignificant, $F(1, 39) = .14$, $p = .71$, partial $\eta^2 < .01$. Therefore, follow-up tests for simple main effects were not conducted. The univariate test associated with the processing level main effect was not significant, $F(1, 39) = 1.95$, $p = .17$, partial $\eta^2 = .05$. The univariate test associated with the postprandial time main effect was significant, $F(1, 39) = 16.93$, $p < .01$, partial $\eta^2 = .30$. The effect sizes indicated that processing level and postprandial time accounted for 5% and 30% of the variance in immediate memory, respectively. The small effect size for processing level was consistent with the insignificant *p* value. However, immediate memory decreased significantly from 30 minutes to 90 minutes with a large effect size (Green & Salkind, 2017, p. 126). These data are visualized in Figure 5.

Figure 5

Profile Plots of Verbal Learning Immediate Memory

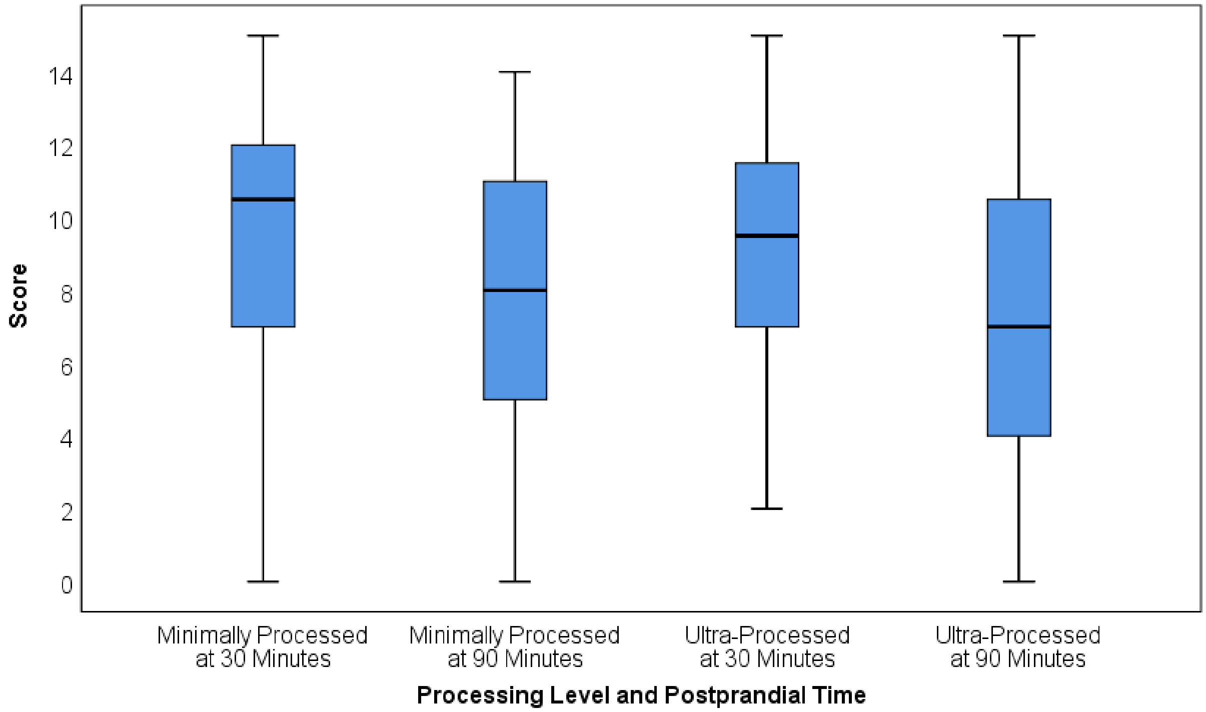


Delayed Recall

Another measure related to verbal learning is delayed recall. Delayed recall is the number of list A words remembered following a 20-minute delay in trial A.6. Figure 6 displays boxplots of the delayed recall data.

Figure 6

Box Plots of Verbal Learning Delayed Recall



No outliers were present in the data. The highest mean delayed recall score was in the minimally processed group at 30 minutes (*M* = 9.78, *SD* = 3.63), followed by the ultra-processed group at 30 minutes (*M* = 9.12, *SD* = 3.75), followed by the minimally processed group at 90 minutes (*M* = 7.83, *SD* = 3.70), followed by the ultra-processed group at 90 minutes (*M* = 7.15, *SD* = 4.35).

A two-way within-subjects Analysis of Variance was conducted to evaluate the effect of processing level and postprandial time on delayed recall. The dependent variable was a delayed recall score on a scale from 0 to 15. The within-subjects factors were postprandial time with two levels (30 minutes and 90 minutes) and processing level with two levels (minimally processed and ultra-processed). The resulting test results are available in Table 6.

Table 6

ANOVA Results for Verbal Learning Delayed Recall

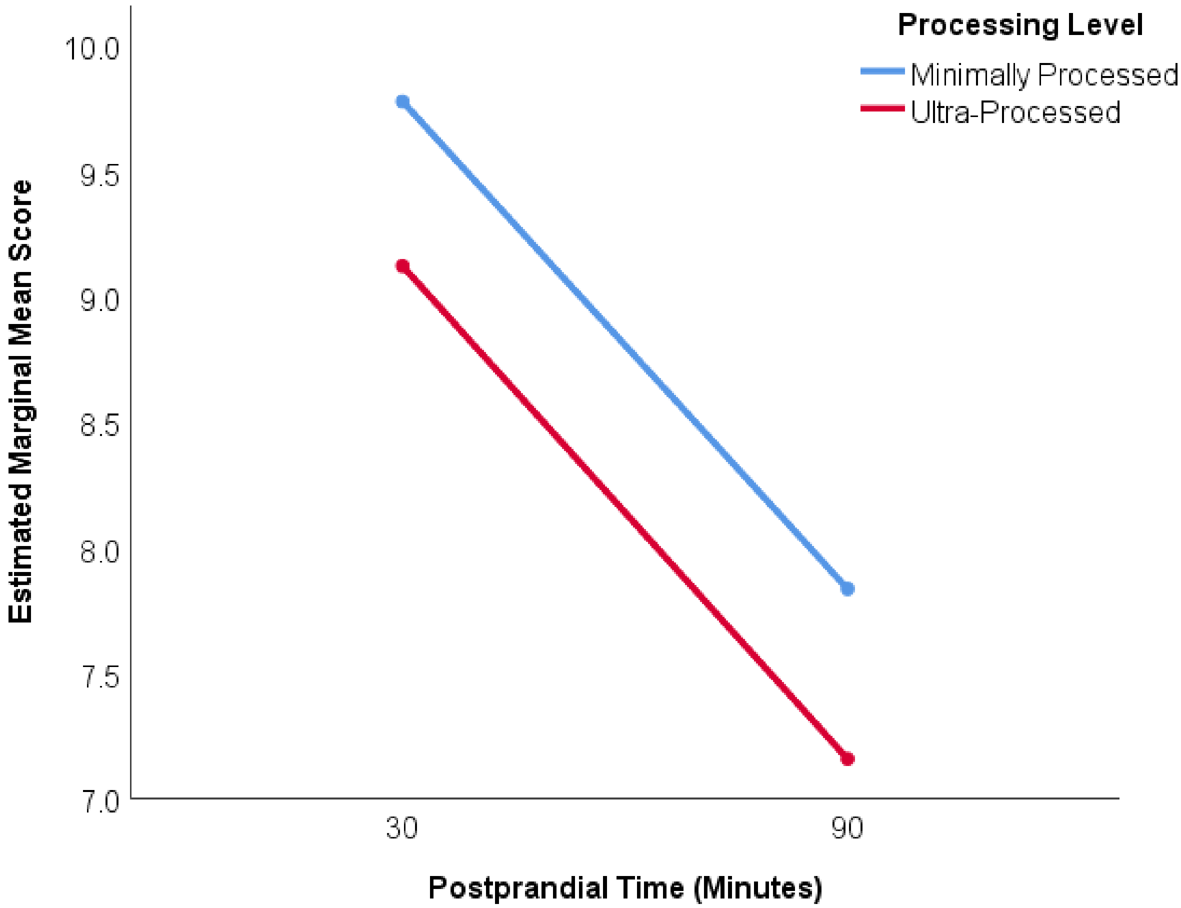
Source	Sum of Squares	*df*	Mean Square	*F*	*p*	η^2
P	17.78	1	17.78	4.16*	.05	.10
Error (P)	166.84	39	4.28			
T	152.67	1	152.67	19.75**	<.01	.34
Error (T)	301.50	39	7.73			
P * T	<.01	1	<.01	<0.01	.98	<.01
Error (P * T)	199.37	39	5.11			

Note. ANOVA = Analysis of Variance; P = Processing Level; T = Postprandial Time.
$^{*}p < .05$. $^{**}p < .01$

The interaction between postprandial time and processing level was found to be nonsignificant, $F(1, 39) < 0.01$, $p = .98$, partial $\eta^2 < .01$. Therefore, follow-up tests for simple main effects were not conducted. The univariate test associated with the processing level main effect was significant, $F(1, 39) = 4.16$, $p = .05$, partial $\eta^2 = .10$. The univariate test associated with the postprandial time main effect was also significant, $F(1, 39) = 19.75$, $p < .01$, partial $\eta^2 = .34$. In summary, delayed recall was significantly greater in the minimally processed group, compared to the ultra-processed group, as well as at 30 minutes, compared to 90 minutes. The effect sizes indicated that processing level and postprandial time accounted for 10% and 34% of the variance in delayed recall, respectively. These effect sizes were considered medium and large, respectively (Green & Salkind, 2017, p. 126). Both effects are visible in Figure 7.

Figure 7

Profile Plots of Verbal Learning Delayed Recall

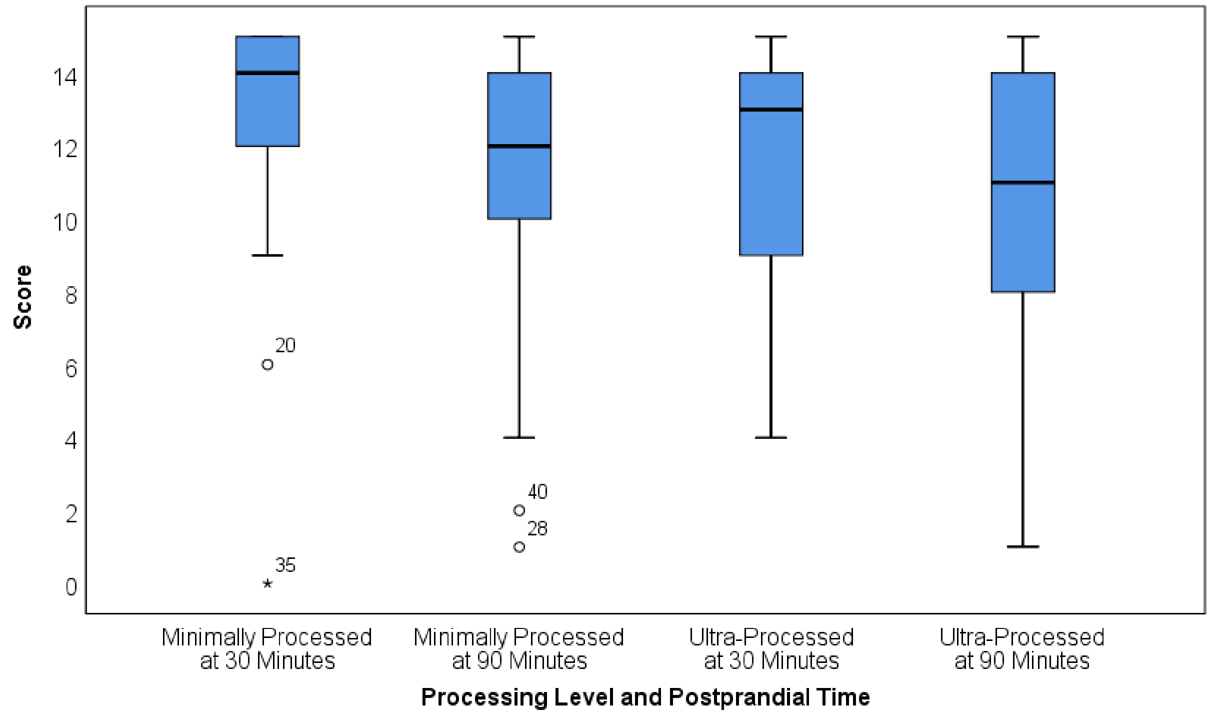


Recognition

Another measure related to verbal learning is recognition. Recognition is the number of list A words correctly identified from a list of 50 options. Figure 8 displays boxplots of the recognition data.

Figure 8

Box Plots of Verbal Learning Recognition



Two outliers were present with low scores in each of the minimally processed groups. Despite these outliers, the highest mean recognition score was in the minimally processed group at 30 minutes (M = 12.97, SD = 2.98), followed by the ultra-processed group at 30 minutes (M = 11.61, SD = 3.31), followed by the minimally processed group at 90 minutes (M = 11.12, SD = 3.94), followed by the ultra-processed group at 90 minutes (M = 10.30, SD = 3.96).

A two-way within-subjects Analysis of Variance was conducted to evaluate the effect of processing level and postprandial time on recognition. The dependent variable was a recognition score on a scale from 0 to 15. The within-subjects factors were postprandial time with two levels (30 minutes and 90 minutes) and processing level with two levels (minimally processed and ultra-processed). The resulting test results are available in Table 7.

Table 7

ANOVA Results for Verbal Learning Recognition

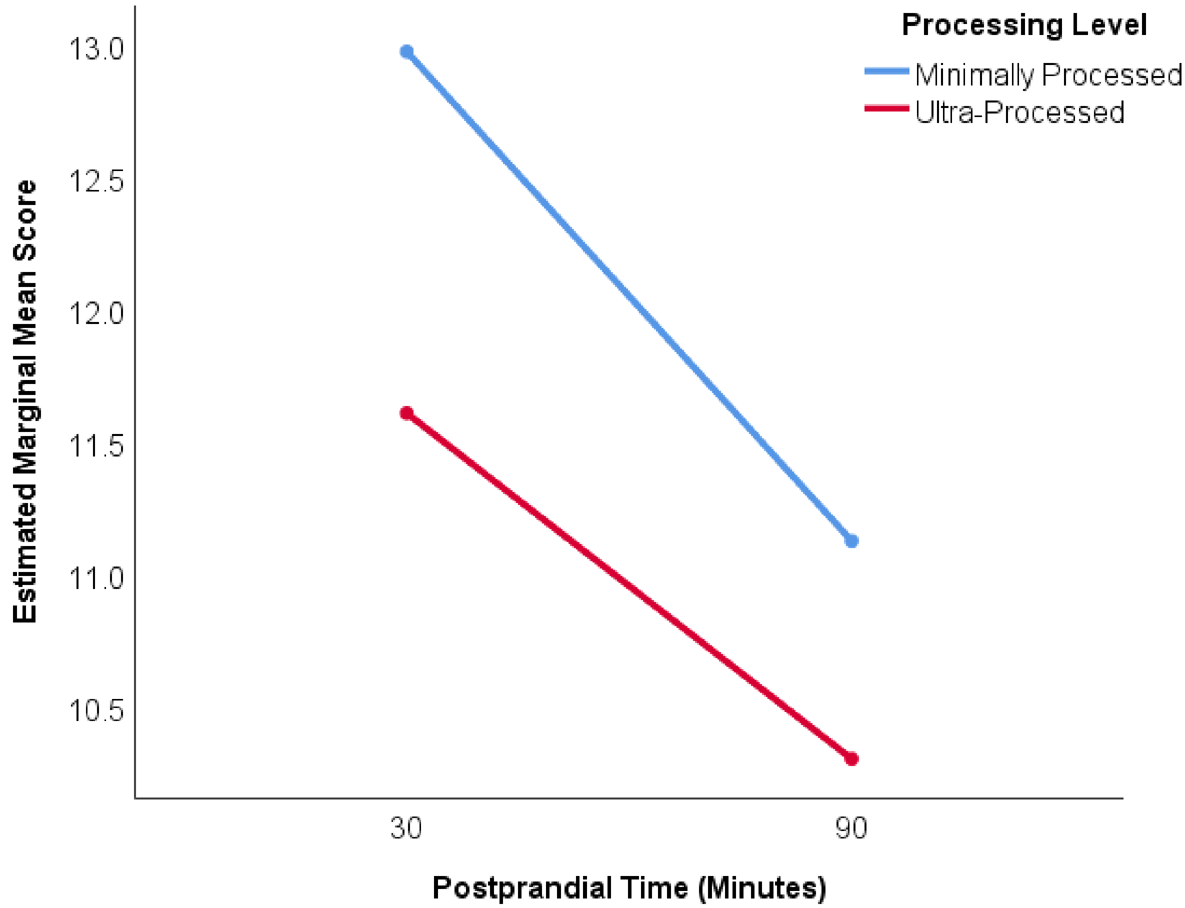
Source	Sum of Squares	*df*	Mean Square	*F*	*p*	η^2
P	48.05	1	48.05	8.76^{*}	.01	.18
Error (P)	213.97	39	5.49			
T	99.72	1	99.72	20.32^{**}	<.01	.34
Error (T)	191.38	39	4.91			
P * T	2.95	1	2.95	0.45	.50	.01
Error (P * T)	253.32	39	6.50			

Note. ANOVA = Analysis of Variance; P = Processing Level; T = Postprandial Time.
$^{*}p < .05$. $^{**}p < .01$

The interaction between postprandial time and processing level was found to be nonsignificant, $F(1, 39) = 0.45$, $p = .50$, partial $\eta^2 = .01$. Therefore, follow-up tests for simple main effects were not conducted. The univariate test associated with the processing level main effect was significant, $F(1, 39) = 8.76$, $p = .01$, partial $\eta^2 = .18$. The univariate test associated with the postprandial time main effect was also significant, $F(1, 39) = 20.32$, $p < .01$, partial $\eta^2 = .34$. In summary, recognition was significantly greater in the minimally processed group, compared to the ultra-processed group, as well as at 30 minutes, compared to 90 minutes. The effect sizes indicated that processing level and postprandial time accounted for 18% and 34% of the variance in recognition, respectively. These effect sizes are both considered to be large (Green & Salkind, 2017, p. 126). Both effects are visible in Figure 9.

Figure 9

Profile Plots of Verbal Learning Recognition

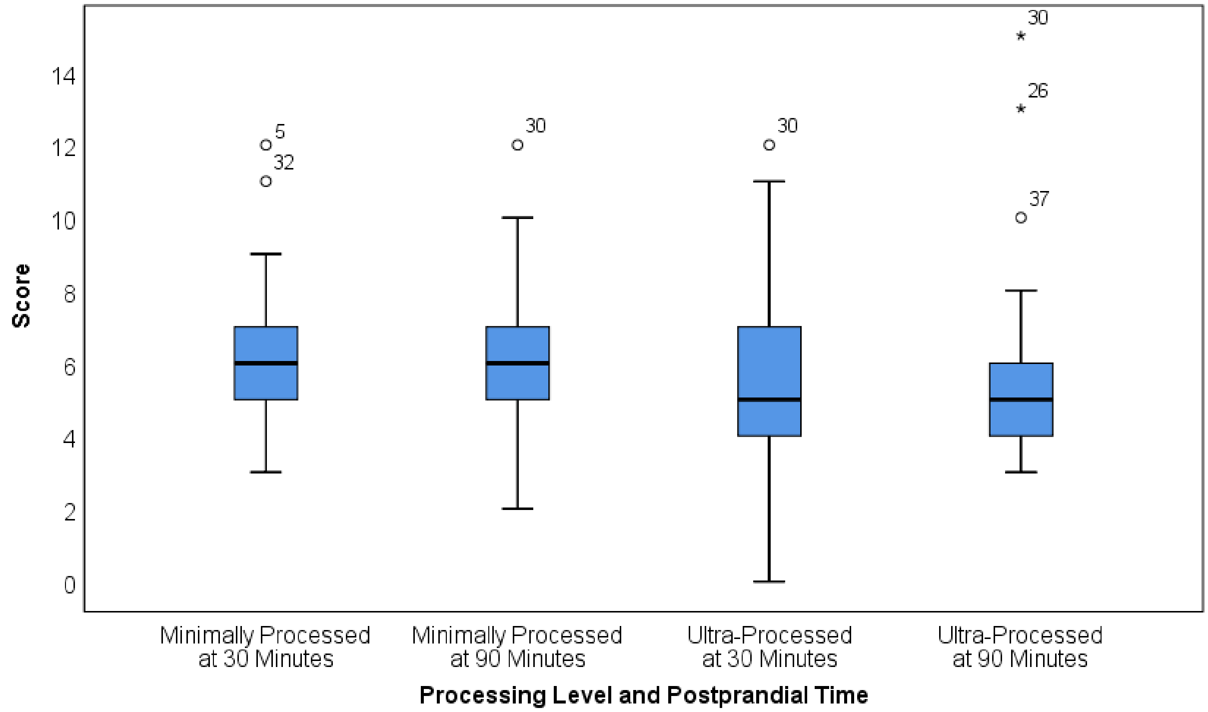


Interference List Score

Another measure related to verbal learning is interference list score. Interference list score is the number of list B words remembered during trial B.1 of the RAVLT. Figure 10 displays boxplots of the interference list score data.

Figure 10

Box Plots of Verbal Learning Interference List Score



Each group of data had one to three outliers at the high end of the distribution. The highest mean interference list score was in the minimally processed group at 30 minutes (*M* = 6.25, *SD* = 1.92), followed by the minimally processed group at 90 minutes (*M* = 6.15, *SD* =1.93), followed by the ultra-processed group at 90 minutes (*M* = 5.60, *SD* = 2.46), followed by the ultra-processed group at 30 minutes (*M* = 5.59, *SD* = 2.47).

A two-way within-subjects Analysis of Variance was conducted to evaluate the effect of processing level and postprandial time on interference list score. The dependent variable was an interference list score on a scale from 0 to 15. The within-subjects factors were postprandial time with two levels (30 minutes and 90 minutes) and processing level with two levels (minimally processed and ultra-processed). The resulting test results are available in Table 8.

Table 8

ANOVA Results for Verbal Learning Interference List Score

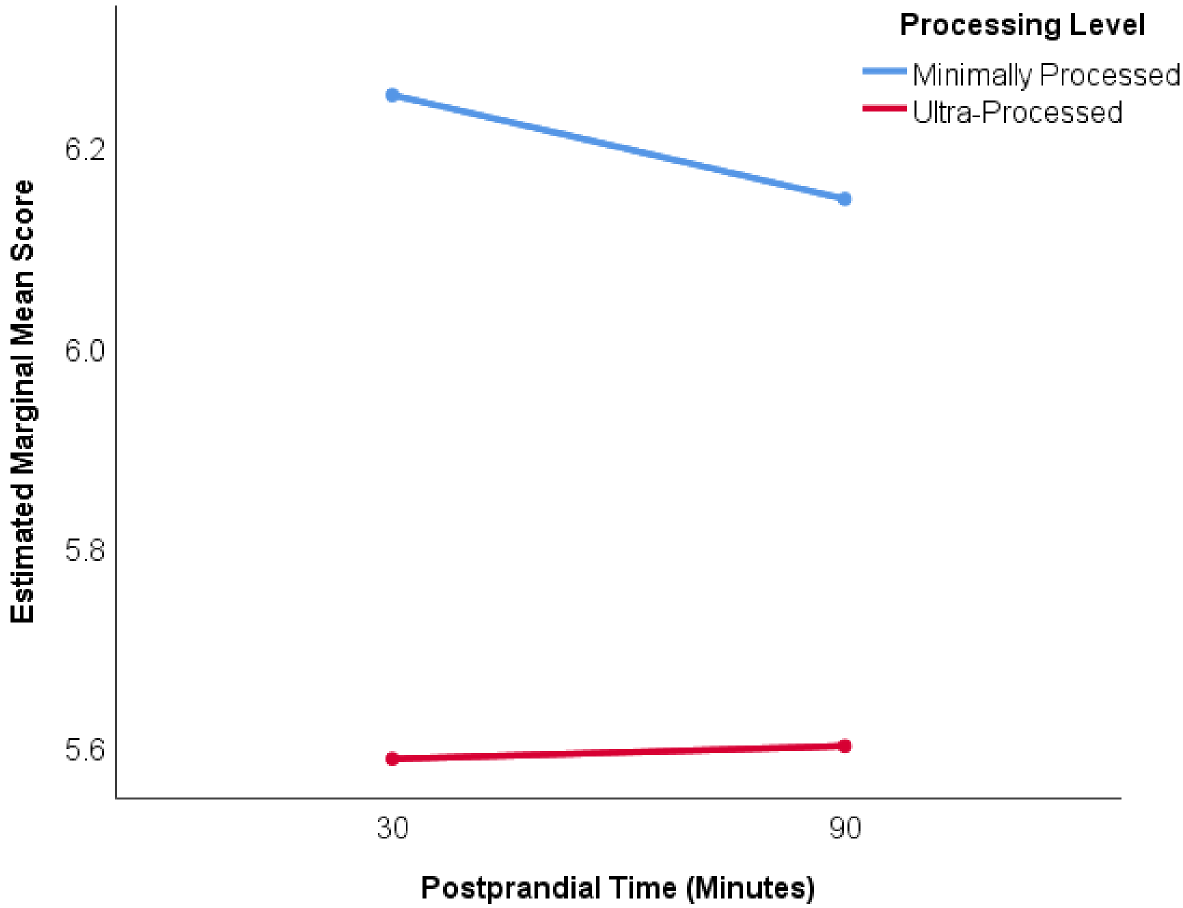
Source	Sum of Squares	*df*	Mean Square	*F*	*p*	η^2
P	14.62	1	14.62	3.99*	.05	.09
Error (P)	142.96	39	3.67			
T	.08	1	.08	0.02	.88	<.01
Error (T)	137.95	39	3.54			
P * T	.14	1	.14	0.06	.81	<.01
Error (P * T)	94.75	39	2.43			

Note. ANOVA = Analysis of Variance; P = Processing Level; T = Postprandial Time.
$^{*}p < .05$. $^{**}p < .01$

The interaction between postprandial time and processing level was found to be nonsignificant, $F(1, 39) = 0.06$, $p = .81$, partial $\eta^2 < .01$. Therefore, follow-up tests for simple main effects were not conducted. The univariate test associated with the processing level main effect was significant, $F(1, 39) = 3.99$, $p = .05$, partial $\eta^2 = .09$. The univariate test associated with the postprandial time main effect was nonsignificant, $F(1, 39) = 0.02$, $p = .88$, partial $\eta^2 < .01$. In summary, interference list score was significantly greater in the minimally processed group, compared to the ultra-processed group. This medium effect size indicated that processing level accounted for 9% of the variance in interference list score (Green & Salkind, 2017, p. 126). This effect is visible in Figure 11.

Figure 11

Profile Plots of Verbal Learning Interference List Score

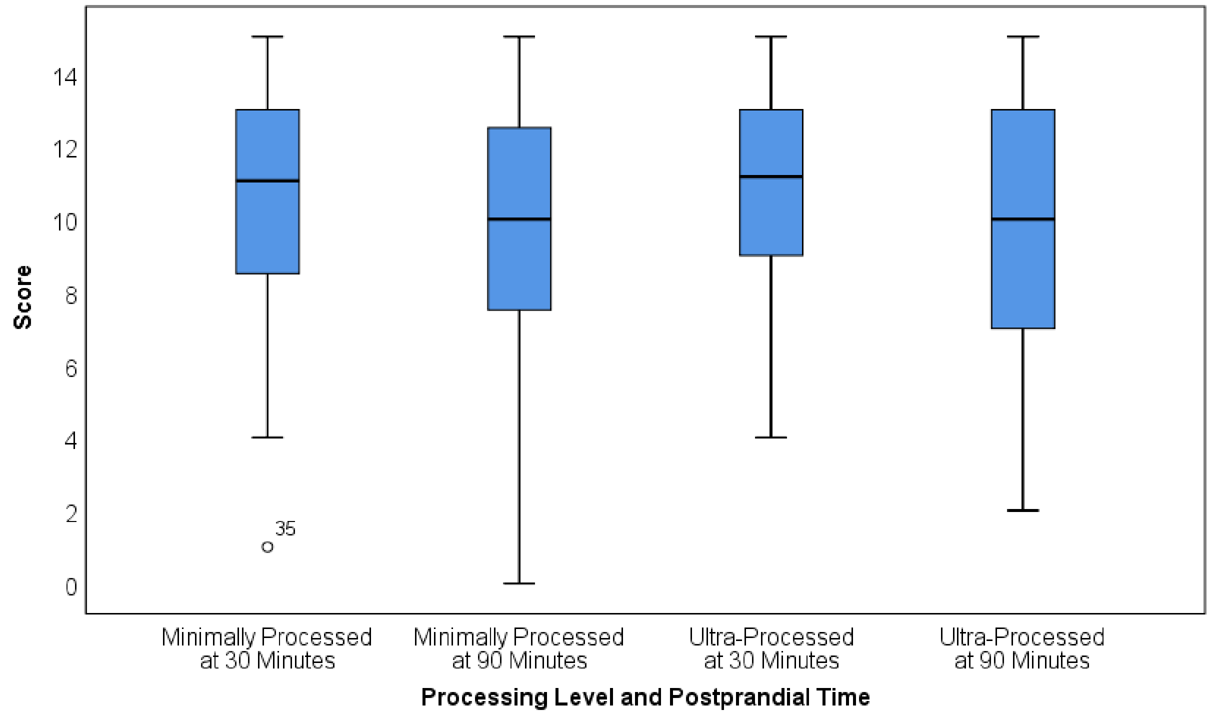


Retention

Another measure related to verbal learning is retention. Retention is the number of list A words remembered following the distractor trial. Figure 12 displays boxplots of the retention data.

Figure 12

Box Plots of Verbal Learning Retention



One outlier was present in the data. The highest mean retention score was in the ultra-processed group at 30 minutes (M = 10.79, SD = 3.16), followed by the minimally processed group at 30 minutes (M = 10.68, SD = 3.11), followed by the ultra-processed group at 90 minutes (M = 9.63, SD = 3.98), followed by the minimally processed group at 90 minutes (M = 9.60, SD = 3.75).

A two-way within-subjects Analysis of Variance was conducted to evaluate the effect of processing level and postprandial time on retention. The dependent variable was a retention score on a scale from 0 to 15. The within-subjects factors were postprandial time with two levels (30 minutes and 90 minutes) and processing level with two levels (minimally processed and ultra-processed). The resulting test results are available in Table 9.

Table 9

ANOVA Results for Verbal Learning Retention

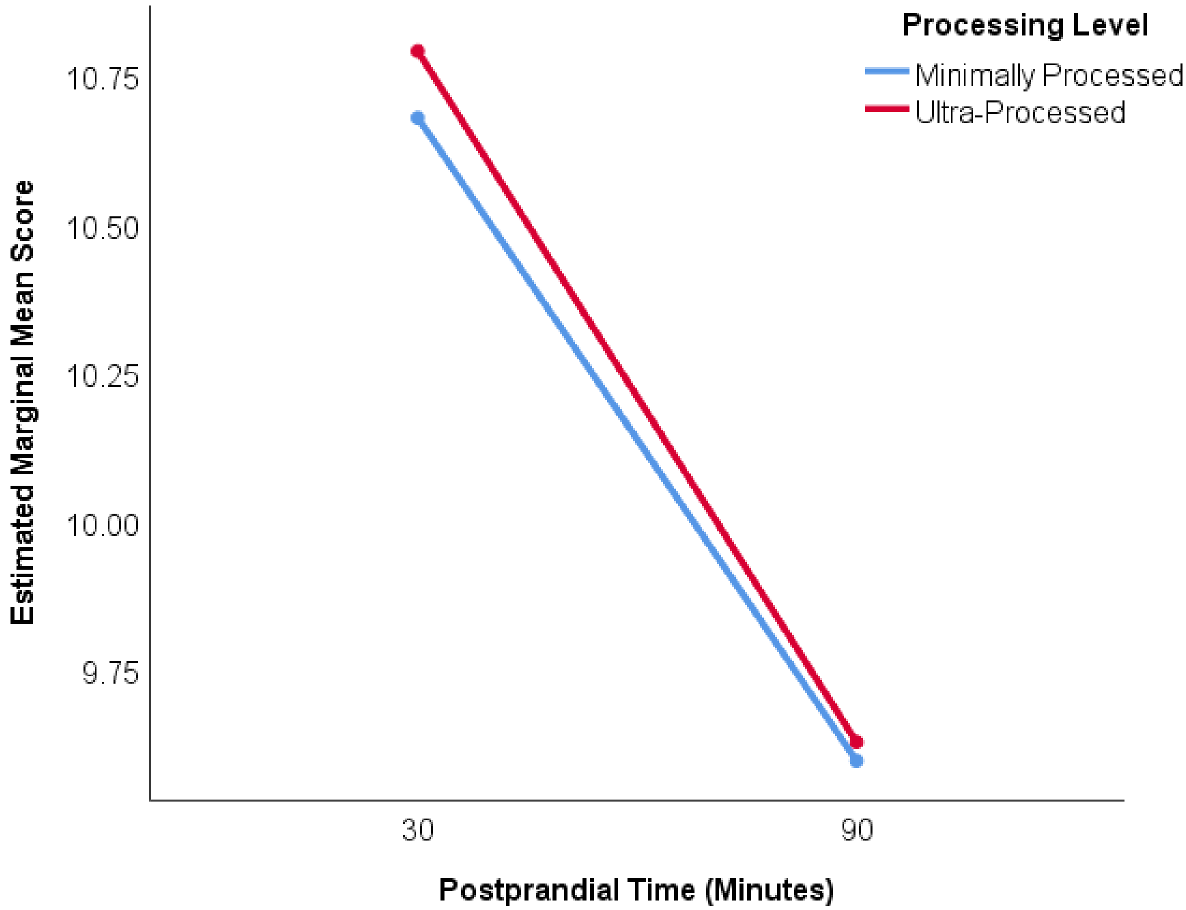
Source	Sum of Squares	*df*	Mean Square	*F*	*p*	η^2
P	.21	1	.21	0.04	.84	<.01
Error (P)	187.92	39	4.82			
T	50.33	1	50.33	15.12^{**}	<.01	.28
Error (T)	129.80	39	3.33			
P * T	.06	1	.06	.01	.93	<.01
Error (P * T)	293.68	39	7.53			

Note. ANOVA = Analysis of Variance; P = Processing Level; T = Postprandial Time.
$^{*}p < .05$. $^{**}p < .01$

The interaction between postprandial time and processing level was found to be nonsignificant, $F(1, 39) = .01$, $p = .93$, partial $\eta^2 < .01$. Therefore, follow-up tests for simple main effects were not conducted. The univariate test associated with the processing level main effect was nonsignificant, $F(1, 39) = 0.04$, $p = .84$, partial $\eta^2 < .01$. However, the univariate test associated with the postprandial time main effect was significant, $F(1, 39) = 15.12$, $p < .01$, partial $\eta^2 = .28$. In summary, retention decreased significantly from 30 minutes to 90 minutes. The effect size indicated that postprandial time accounted for 28% of the variance in retention, which is considered a large effect size (Green & Salkind, 2017, p. 126). This time effect is visible in Figure 13.

Figure 13

Profile Plots of Verbal Learning Retention

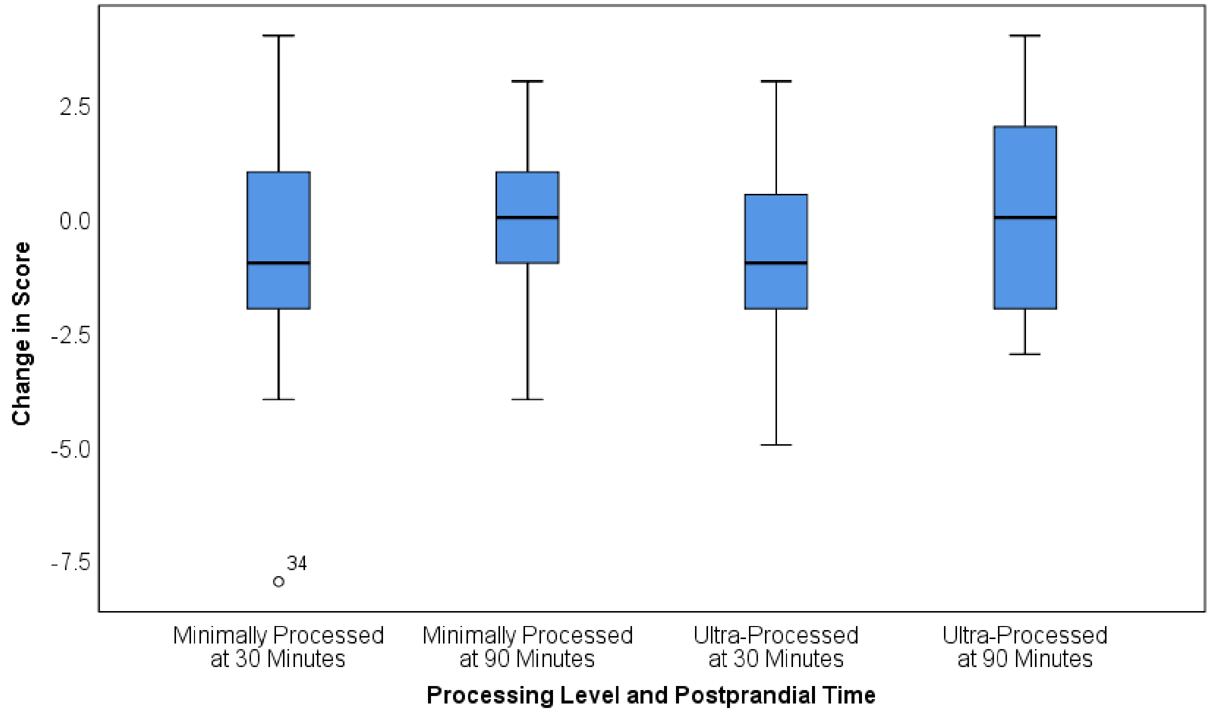


Proactive Interference

Another measure related to verbal learning is proactive interference. Proactive interference is a measure of the negative impact of having already learned list A on subsequently learning the new list, list B. It is calculated as a change in score from trial A.1 to trial B.1 Therefore, the more negative a change is, the more interference there is. Figure 14 displays boxplots of the proactive interference data.

Figure 14

Box Plots of Verbal Learning Proactive Interference



One outlier was present in the data for the minimally processed meal at 30 minutes. The most negative mean proactive interference score was in the ultra-processed group at 30 minutes (*M* = -1.00, *SD* = 1.88), followed by the minimally processed group at 30 minutes (*M* = -0.72, *SD* = 2.40), followed by the minimally processed group at 90 minutes (*M* = 0.03, *SD* = 1.83), followed by the ultra-processed group at 90 minutes (*M* = 0.07, *SD* = 1.97).

A two-way within-subjects Analysis of Variance was conducted to evaluate the effect of processing level and postprandial time on verbal learning proactive interference. The dependent variable was a proactive interference score on a scale from -15 to 15. The within-subjects factors were postprandial time with two levels (30 minutes and 90 minutes) and processing level with two levels (minimally processed and ultra-processed). The resulting test results are available in Table 10.

Table 10

ANOVA Results for Verbal Learning Proactive Interference

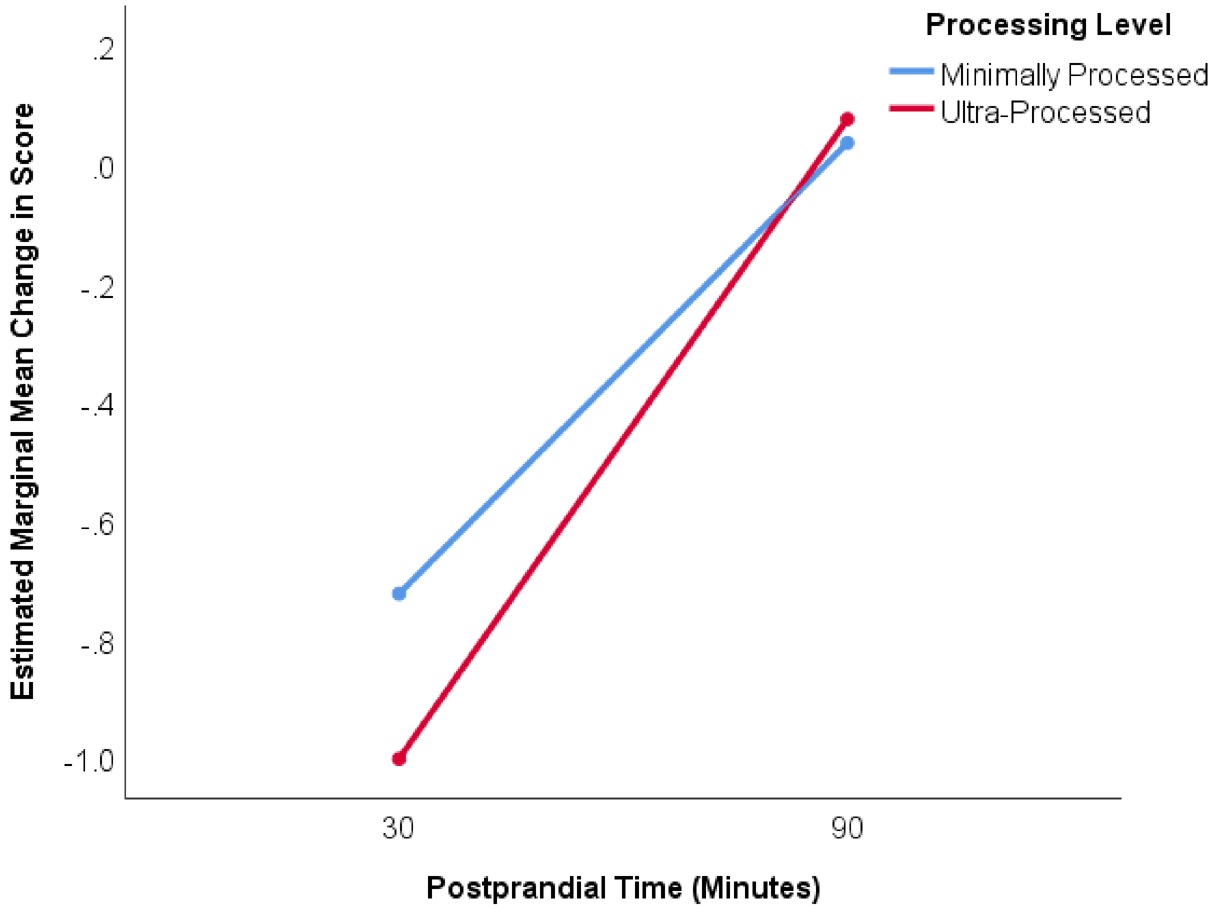
Source	Sum of Squares	*df*	Mean Square	*F*	*p*	η^2
P	0.57	1	0.57	0.11	.74	<.01
Error (P)	201.09	39	5.16			
T	33.80	1	33.80	9.11^{**}	<.01	.19
Error (T)	144.71	39	3.71			
P * T	1.01	1	1.01	0.30	.59	.01
Error (P * T)	133.57	39	3.42			

Note. ANOVA = Analysis of Variance; P = Processing Level; T = Postprandial Time.
$^{*}p < .05$. $^{**}p < .01$

The interaction between postprandial time and processing level was found to be nonsignificant, $F(1, 39) = 0.30$, $p = .59$, partial $\eta^2 = .01$. Therefore, follow-up tests for simple main effects were not conducted. The univariate test associated with the processing level main effect was nonsignificant, $F(1, 39) = 0.11$, $p = .74$, partial $\eta^2 < .01$. The univariate test associated with the postprandial time main effect was significant, $F(1, 39) = 9.11$, $p < .01$, partial $\eta^2 = .19$. The effect size indicated that postprandial time accounted for 19% of the variance in proactive interference, which is considered a large effect size (Green & Salkind, 2017, p. 126). The time effect, visible in Figure 15, indicated that there was less proactive interference (i.e., a more positive change from trial A.1 to B.1) at 90 minutes, as opposed to 30 minutes.

Figure 15

Profile Plots of Verbal Learning Proactive Interference

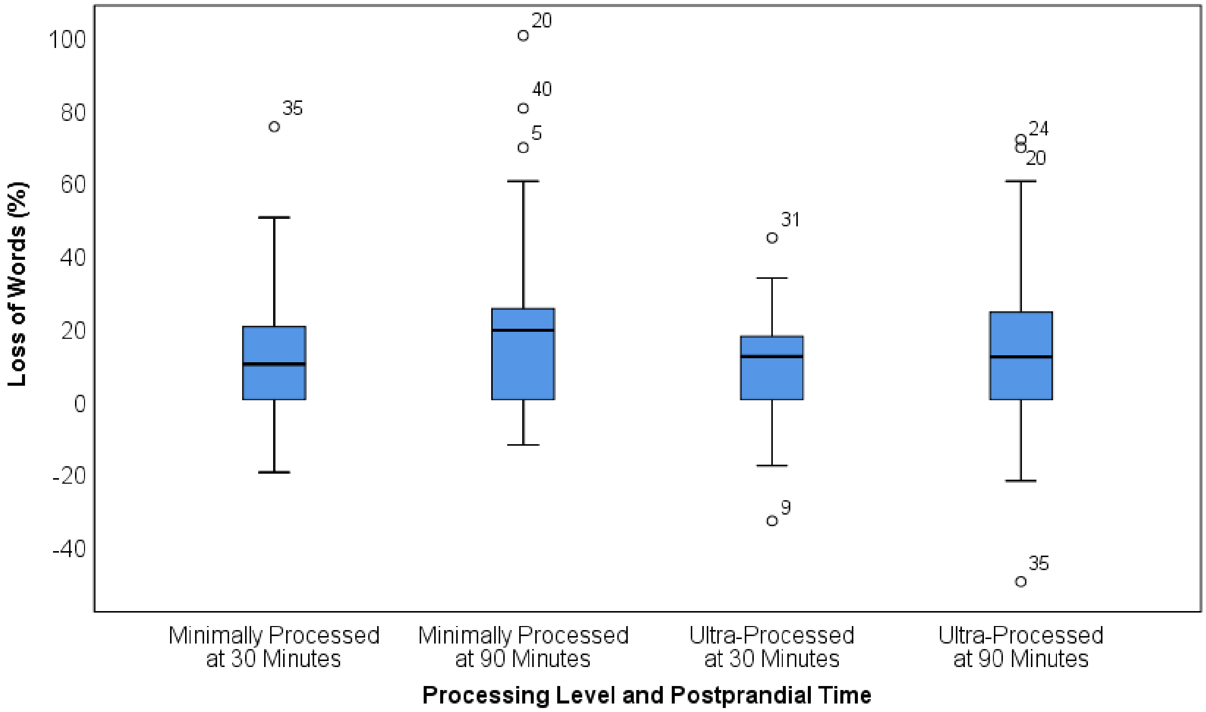


Retroactive Interference

The final measure related to verbal learning is retroactive interference. Retroactive interference is the negative impact of learning something new on the recall of previously learned material. This concept is defined as the percentage of words lost from trial A.5 to A.6, due to the presumed impact of interference trial B.1. In this concept, a more positive value indicates greater retroactive interference. Figure 16 displays boxplots of the retroactive interference data.

Figure 16

Box Plots of Verbal Learning Retroactive Interference



One to three outliers were present in each group. The highest mean retroactive interference was in the minimally processed group at 90 minutes (M = 21.15, SD = 24.08), followed by the ultra-processed group at 90 minutes (M = 15.33, SD = 23.87), followed by the minimally processed group at 30 minutes (M = 13.39, SD = 16.93), followed by the ultra-processed group at 30 minutes (M = 10.95, SD = 14.55).

A two-way within-subjects Analysis of Variance was conducted to evaluate the effect of processing level and postprandial time on retroactive interference. The dependent variable was retroactive interference on a scale from -100 to 100. The within-subjects factors were postprandial time with two levels (30 minutes and 90 minutes) and processing level with two levels (minimally processed and ultra-processed). The resulting test results are available in Table 11.

Table 11

ANOVA Results for Verbal Learning Retroactive Interference

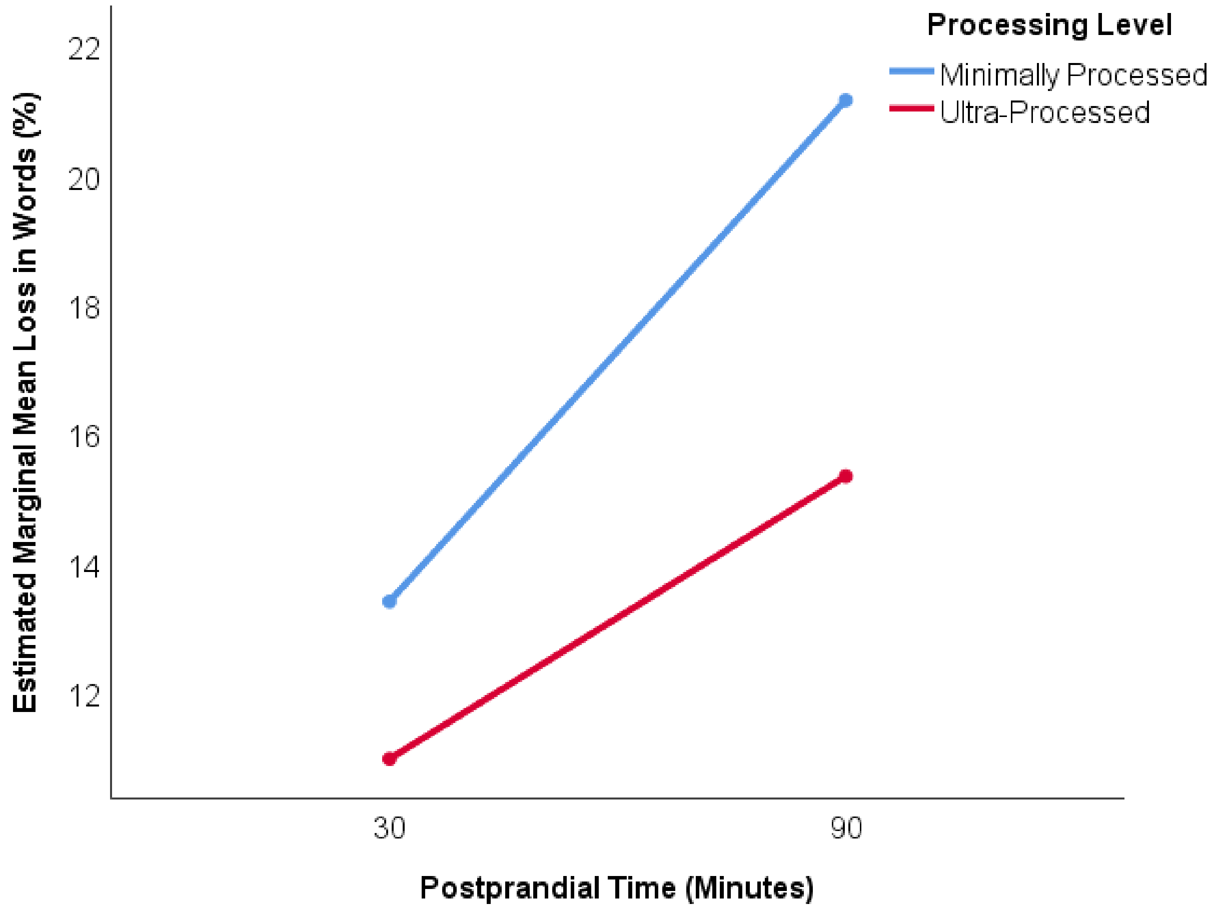
Source	Sum of Squares	*df*	Mean Square	*F*	*p*	η^2
P	681.55	1	681.55	2.25	.14	.05
Error (P)	11,795.94	39	302.46			
T	1,472.00	1	1,472.00	4.44*	.04	.10
Error (T)	12,941.12	39	331.82			
P * T	114.51	1	114.51	0.51	.48	.01
Error (P * T)	8,835.88	39	226.56			

Note. ANOVA = Analysis of Variance; P = Processing Level; T = Postprandial Time.
$^{*}p < .05$. $^{**}p < .01$

The interaction between postprandial time and processing level was found to be nonsignificant, $F(1, 39) = .51$, $p = .48$, partial $\eta^2 = .01$. Therefore, follow-up tests for simple main effects were not conducted. The univariate test associated with the processing level main effect was nonsignificant, $F(1, 39) = 2.25$, $p = .14$, partial $\eta^2 = .05$. The univariate test associated with the postprandial time main effect was significant, $F(1, 39) = 4.44$, $p = .04$, partial $\eta^2 = .10$. Retroactive interference increased significantly from 30 to 90 minutes. The effect size indicated that postprandial time accounted for 10% of the variance in retroactive interference, which is considered a medium effect size (Green & Salkind, 2017, p. 126). This time effect is displayed in Figure 17.

Figure 17

Profile Plots of Verbal Learning Retroactive Interference



Hypotheses 4–6: Phonemic Fluency Results

There are six specific measures related to phonemic fluency. The primary measure of phonemic fluency is phonemic fluency score, the summed score on three trials (i.e., three letters) of the phonemic fluency test. Perseverations are repetitions of the same word in a given trial. Intrusions are incorrect words, including those that do not fit the category given. A cluster is a sequence of words that are homonyms, differ only by a vowel sound, or start with the same first two letters. Switches are the number of transitions between one cluster and the next. Cluster size is defined as the count of words in a given cluster, starting with the second word. Therefore, total

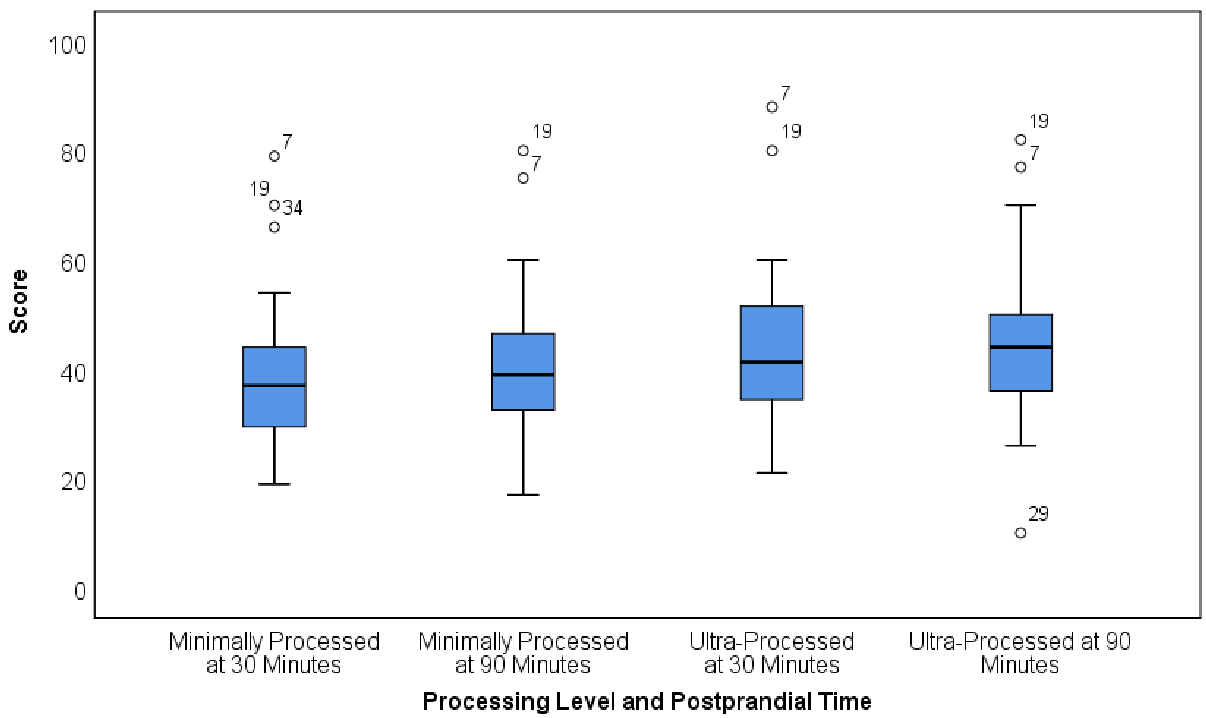
cluster size is the sum of all cluster sizes for all three trials in a phonemic fluency test. Average cluster size is defined as the total cluster size divided by the total number of clusters.

Phonemic Fluency Score

The primary measure of phonemic fluency is phonemic fluency score. Phonemic fluency score is the summed performance of three trials of a phonemic fluency test. In each trial, participants are asked to name as many words as possible in one minute that begin with a certain letter. Figure 18 displays boxplots of the phonemic fluency score data.

Figure 18

Box Plots of Phonemic Fluency Score



Two to three outliers were present in each group. The highest mean phonemic fluency score was in the ultra-processed group at 90 minutes (M = 44.93, SD = 14.24), followed by the ultra-processed group at 30 minutes (M = 43.32, SD = 14.14), followed by the minimally processed group at 90 minutes (M = 40.59, SD = 13.33), followed by the minimally processed group at 30 minutes (M = 38.29, SD = 12.87).

A two-way within-subjects Analysis of Variance was conducted to evaluate the effect of processing level and postprandial time on phonemic fluency score. The dependent variable was a phonemic fluency score with a minimum score of zero and no upper limit. The within-subjects factors were postprandial time with two levels (30 minutes and 90 minutes) and processing level with two levels (minimally processed and ultra-processed). The resulting test results are available in Table 12.

Table 12

ANOVA Results for Phonemic Fluency Score

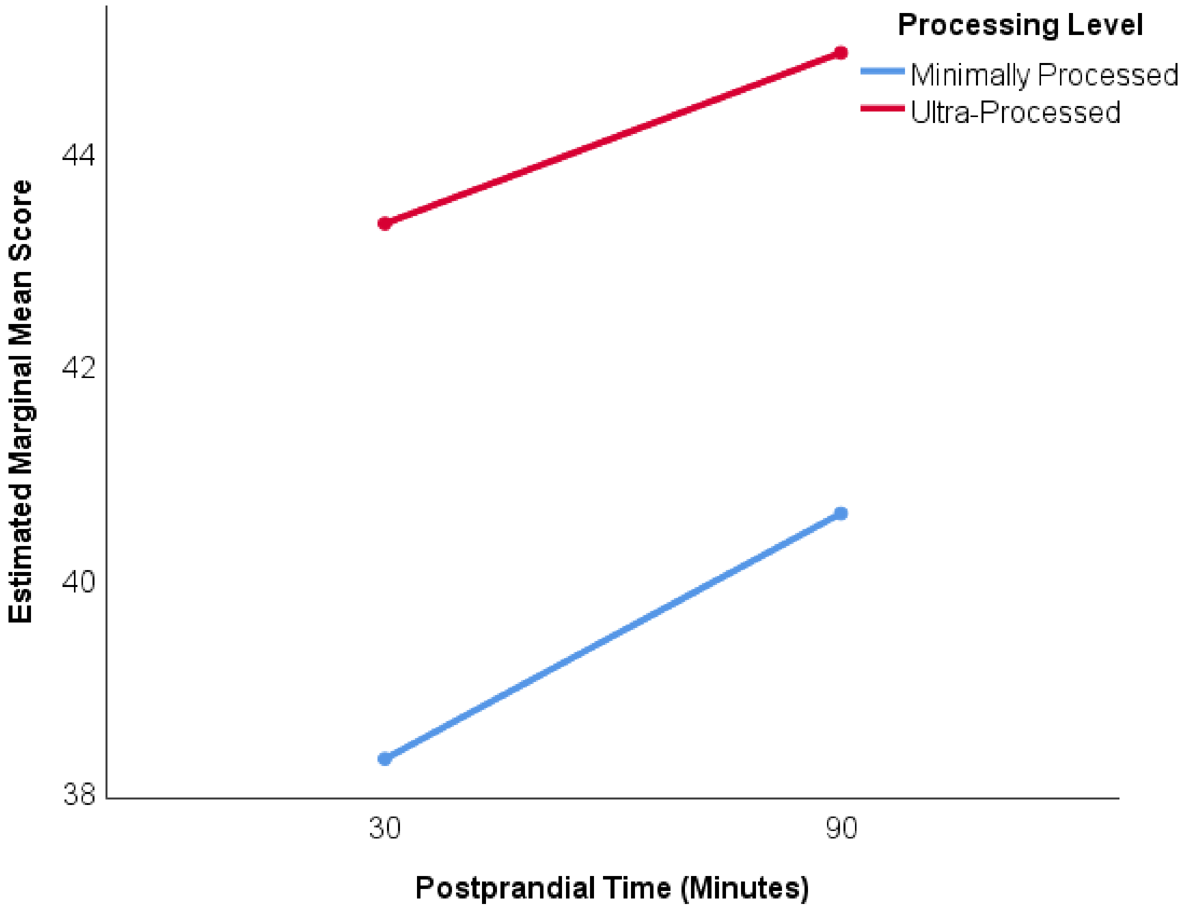
Source	Sum of Squares	*df*	Mean Square	*F*	*p*	η^2
P	877.51	1	877.51	24.50^{**}	<.01	.39
Error (P)	1,396.74	39	35.81			
T	153.29	1	153.29	4.30^{*}	.04	.10
Error (T)	1,391.74	39	35.69			
P * T	4.93	1	4.93	0.18	.67	<.01
Error (P * T)	1,048.48	39	26.88			

Note. ANOVA = Analysis of Variance; P = Processing Level; T = Postprandial Time.
$^{*}p < .05$. $^{**}p < .01$

The interaction between postprandial time and processing level was found to be nonsignificant, $F(1, 39) = 0.18$, $p = .67$, partial $\eta^2 < .01$. Therefore, follow-up tests for simple main effects were not conducted. The univariate test associated with the processing level main effect was significant, $F(1, 39) = 24.50$, $p < .01$, partial $\eta^2 = .39$. The univariate test associated with the postprandial time main effect was also significant, $F(1, 39) = 4.30$, $p = .04$, partial $\eta^2 = .10$. Phonemic fluency was significantly greater in the ultra-processed group, compared to the minimally processed group as well as at 90 minutes, compared to 30 minutes. The effect sizes indicated that processing level and postprandial time accounted for 39% and 10% of the variance in phonemic fluency scores, respectively. These effect sizes were considered large and medium, respectively (Green & Salkind, 2017, p. 126). Both effects are visible in Figure 19.

Figure 19

Profile Plots of Phonemic Fluency Score

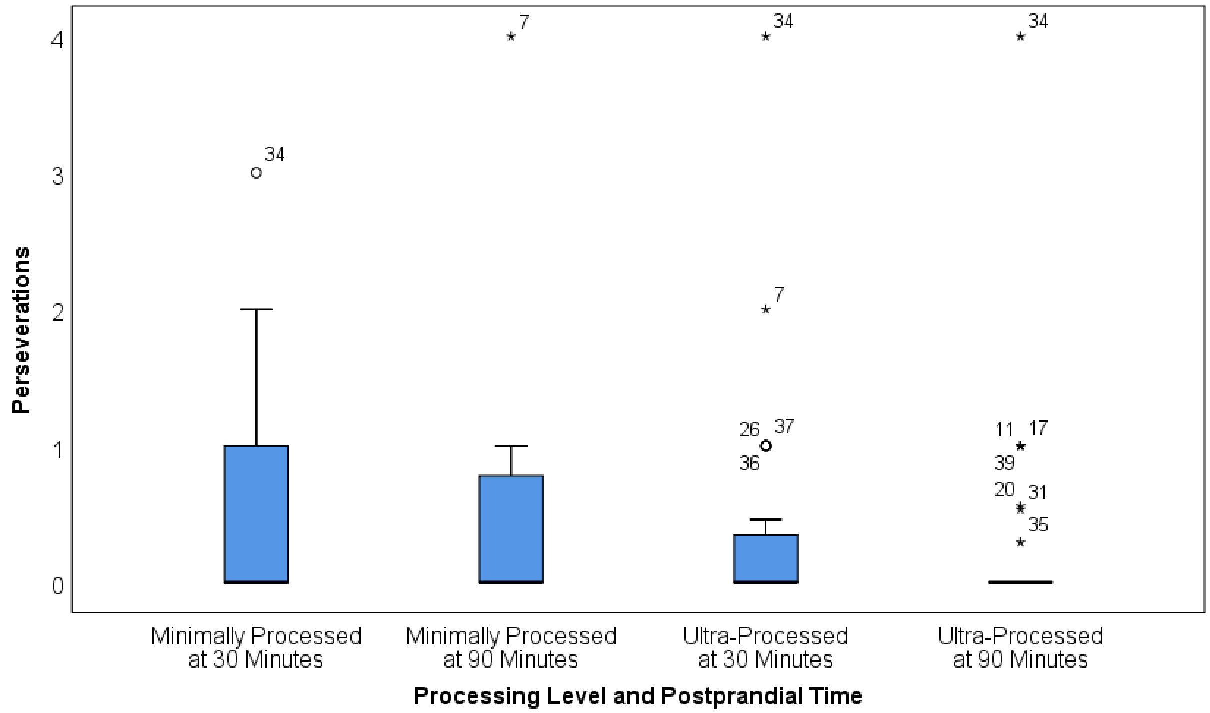


Phonemic Fluency Perseverations

Another measure related to phonemic fluency is the count of perseverations. Perseverations are repeated words in a verbal fluency test. Figure 20 displays boxplots of the perseverations data in the phonemic fluency test.

Figure 20

Box Plots of Phonemic Fluency Perseverations



One to seven outliers were present in each group. The highest mean number of perseverations was in the minimally processed group at 30 minutes (*M* = 0.45, *SD* = 0.78), followed by the minimally processed group at 90 minutes (*M* = 0.36, *SD* = 0.73), followed by the ultra-processed group at 30 minutes (*M* = 0.33, *SD* = 0.75), followed by the ultra-processed group at 90 minutes (*M* = 0.26, *SD* = 0.70).

A two-way within-subjects Analysis of Variance was conducted to evaluate the effect of processing level and postprandial time on phonemic fluency perseverations. The dependent variable was the number of perseverations with a minimum score of zero and no upper limit. The within-subjects factors were postprandial time with two levels (30 minutes and 90 minutes) and processing level with two levels (minimally processed and ultra-processed). The resulting test results are available in Table 13.

Table 13

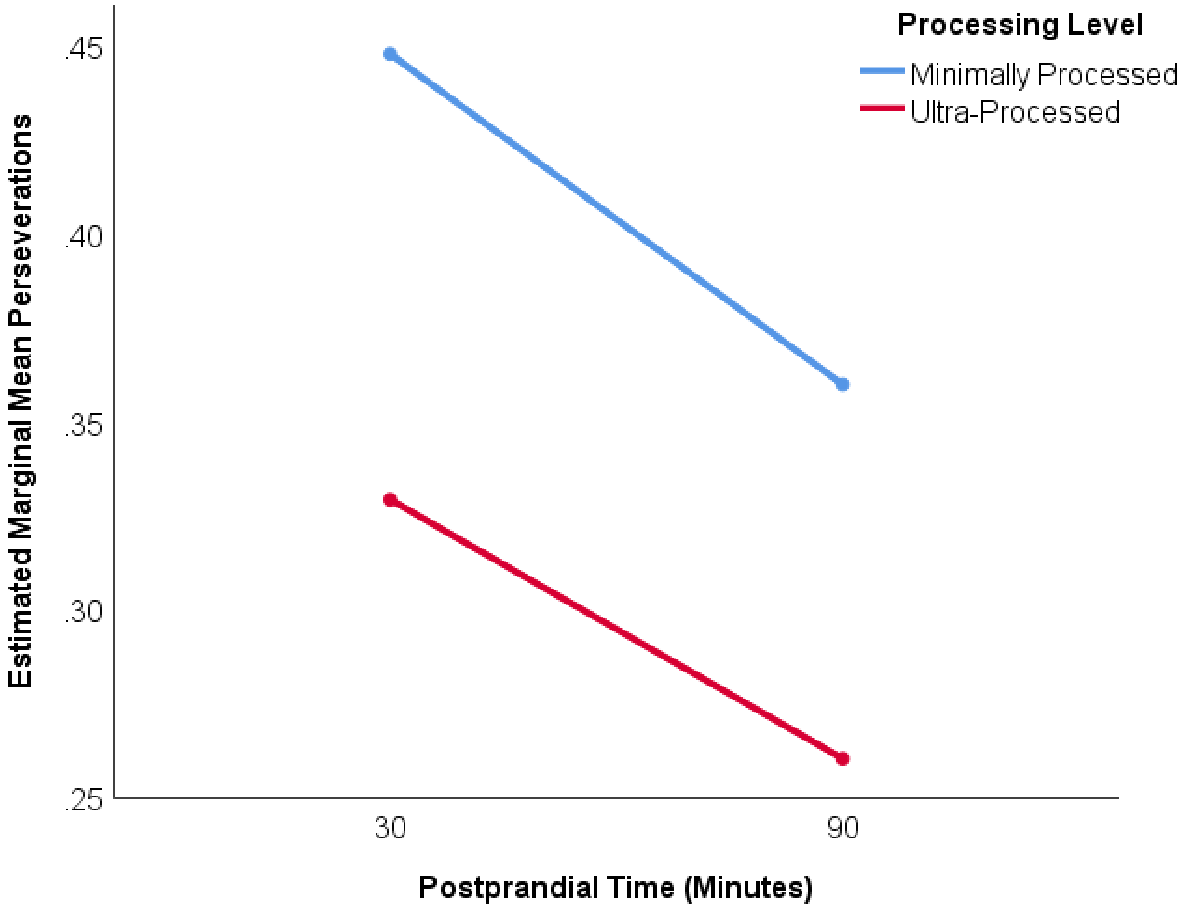
Source	Sum of Squares	*df*	Mean Square	*F*	*p*	η^2
P	0.48	1	0.48	1.35	.25	.03
Error (P)	13.84	39	0.35			
T	0.25	1	0.25	0.73	.40	.02
Error (T)	13.24	39	0.34			
P * T	<0.01	1	<0.01	0.01	.93	<.01
Error (P * T)	16.67	39	0.43			

Note. ANOVA = Analysis of Variance; P = Processing Level; T = Postprandial Time.
$^{*}p < .05$. $^{**}p < .01$

The interaction between postprandial time and processing level was found to be nonsignificant, $F(1, 39) = 0.01$, $p = .93$, partial $\eta^2 < .01$. Therefore, follow-up tests for simple main effects were not conducted. The univariate test associated with the processing level main effect was nonsignificant, $F(1, 39) = 1.35$, $p = .25$, partial $\eta^2 = .03$. The univariate test associated with the postprandial time main effect was also nonsignificant, $F(1, 39) = 0.73$, $p = .40$, partial $\eta^2 = .02$. The estimated marginal means are displayed in Figure 21.

Figure 21

Profile Plots of Phonemic Fluency Perseverations

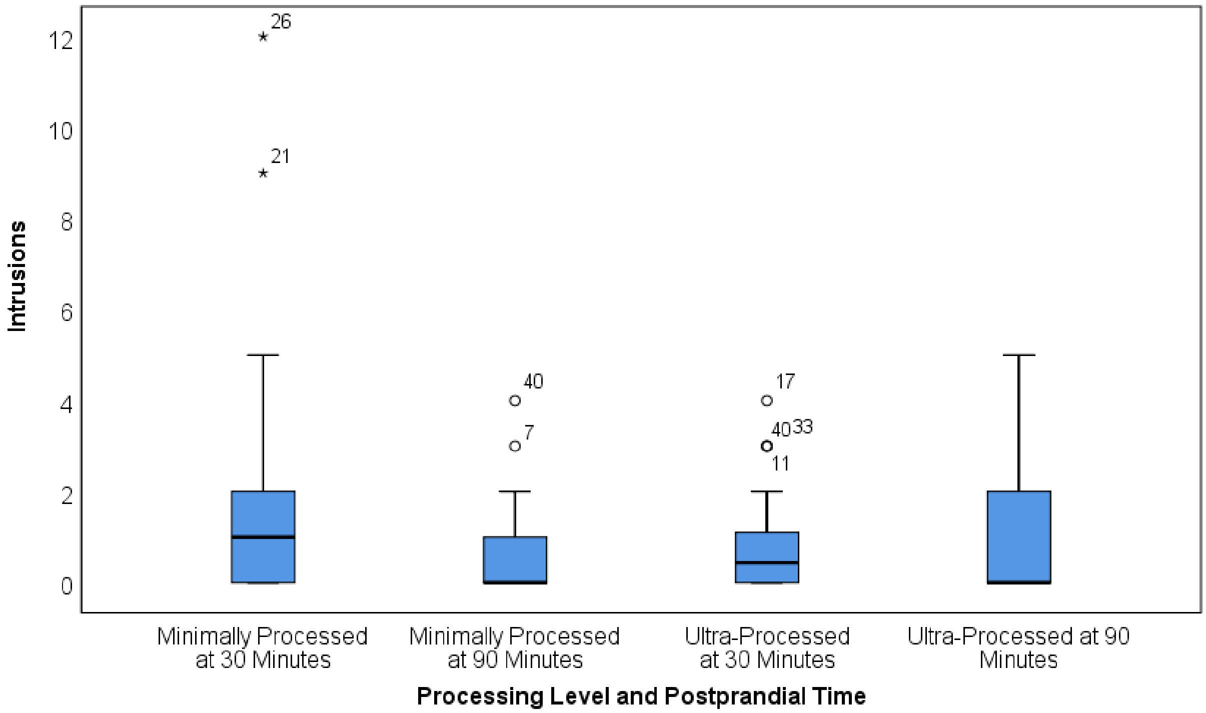


Phonemic Fluency Intrusions

Another measure related to phonemic fluency is the count of intrusions. Intrusions are incorrect or invalid words in a verbal fluency test. Figure 22 displays boxplots of the intrusions data in the phonemic fluency test.

Figure 22

Box Plots of Phonemic Fluency Intrusions



Zero to four outliers were present in each group. The highest intrusion mean was in the minimally processed group at 30 minutes (M = 1.52, SD = 2.45), followed by the ultra-processed group at 90 minutes (M = 1.03, SD = 1.41), followed by the ultra-processed group at 30 minutes (M = 0.85, SD = 1.08), followed by the minimally processed group at 90 minutes (M = 0.58, SD = 0.93).

A two-way within-subjects Analysis of Variance was conducted to evaluate the effect of processing level and postprandial time on phonemic fluency intrusions. The dependent variable was the number of intrusions with a minimum score of zero and no upper limit. The within-subjects factors were postprandial time with two levels (30 minutes and 90 minutes) and processing level with two levels (minimally processed and ultra-processed). The resulting test results are available in Table 14.

Table 14

ANOVA Results for Phonemic Fluency Intrusions

Source	Sum of Squares	*df*	Mean Square	*F*	*p*	η^2
P	.44	1	0.44	0.25	.62	.01
Error (P)	68.84	39	1.77			
T	5.65	1	5.65	2.38	.13	.06
Error (T)	92.47	39	2.37			
P * T	12.50	1	12.50	7.80*	.01	.17
Error (P * T)	62.48	39	1.60			

Note. ANOVA = Analysis of Variance; P = Processing Level; T = Postprandial Time.
$^{*}p < .05$. $^{**}p < .01$

The univariate test associated with the processing level main effect was nonsignificant, F(1, 39) = 0.25, p = .62, partial η^2 = .01. The univariate test associated with the postprandial time main effect was also nonsignificant, F(1, 39) = 2.38, p = .13, partial η^2 = .06. The interaction between postprandial time and processing level was found to be significant, $F(1, 39) = 7.80$, p = .01, partial η^2 = .17. This interaction had a large effect size, accounting for 17% of the variation in phonemic fluency intrusions (Green & Salkind, 2017, p. 126). Therefore, follow-up tests for simple main effects were conducted with a paired-samples *t*-test (Table 15).

Table 15

Paired-Samples t-Test Results for Phonemic Fluency Intrusions

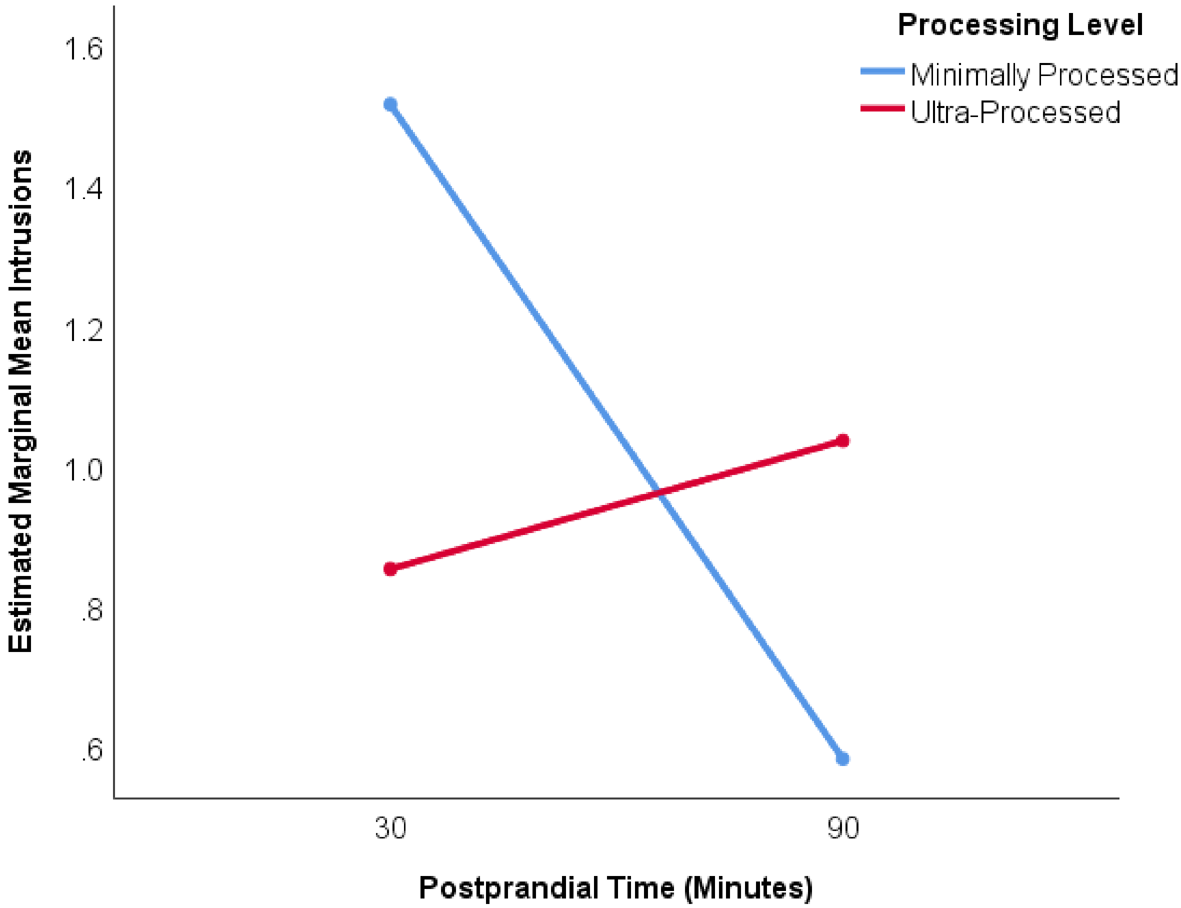
	Paired Differences							
				95% CI				
	M	*SD*	*SE*	Lower	Upper	*t*	*df*	*p*
Postprandial Time								
Pair 1 MP30 – MP90	0.93	2.48	0.39	0.14	1.73	2.39*	39	.02
Pair 2 UP30 – UP90	-.18	1.34	0.21	-0.61	0.25	-0.86	39	.39
Processing Level								
Pair 1 MP30 – UP30	0.66	2.26	0.36	-0.06	1.39	1.85	39	.07
Pair 2 MP90 – UP90	-.45	1.27	0.20	-0.86	-0.05	-2.27	39	.03

Note. MP30 = Minimally Processed at 30 Minutes; MP90 = Minimally Processed at 90 Minutes; UP30 = Ultra-Processed at 30 Minutes; UP90 = Ultra-Processed at 90 Minutes
$^{*}p < .025$ for the smallest p value and $p < .05$ for the next smallest p value

Pairwise comparisons were controlled for familywise error rate using Holm's sequential Bonferroni procedure. Out of the two comparisons in each test, the one with the smallest p value was compared to $\alpha = .05/2 = .025$. The next smallest p value was compared to $\alpha = .05/1 = .05$ (Green & Salkind, 2017, p. 183). For those eating minimally processed meals, intrusions decreased significantly from 30 minutes ($M = 1.52$, $SD = 2.45$) to 90 minutes ($M = 0.58$, $SD = 0.93$), $t(39) = 2.39$, $p = .02$. At 90 minutes, intrusions were higher for those eating ultra-processed meals ($M = 1.03$, $SD = 1.41$), compared to those eating minimally processed meals ($M = 0.58$, $SD = 0.93$), but due to the correction for familywise error rate, this difference did not reach statistical significance ($t(39) = -2.27$, $p = .03$). The estimated marginal means are displayed graphically in Figure 23.

Figure 23

Profile Plots of Phonemic Fluency Intrusions

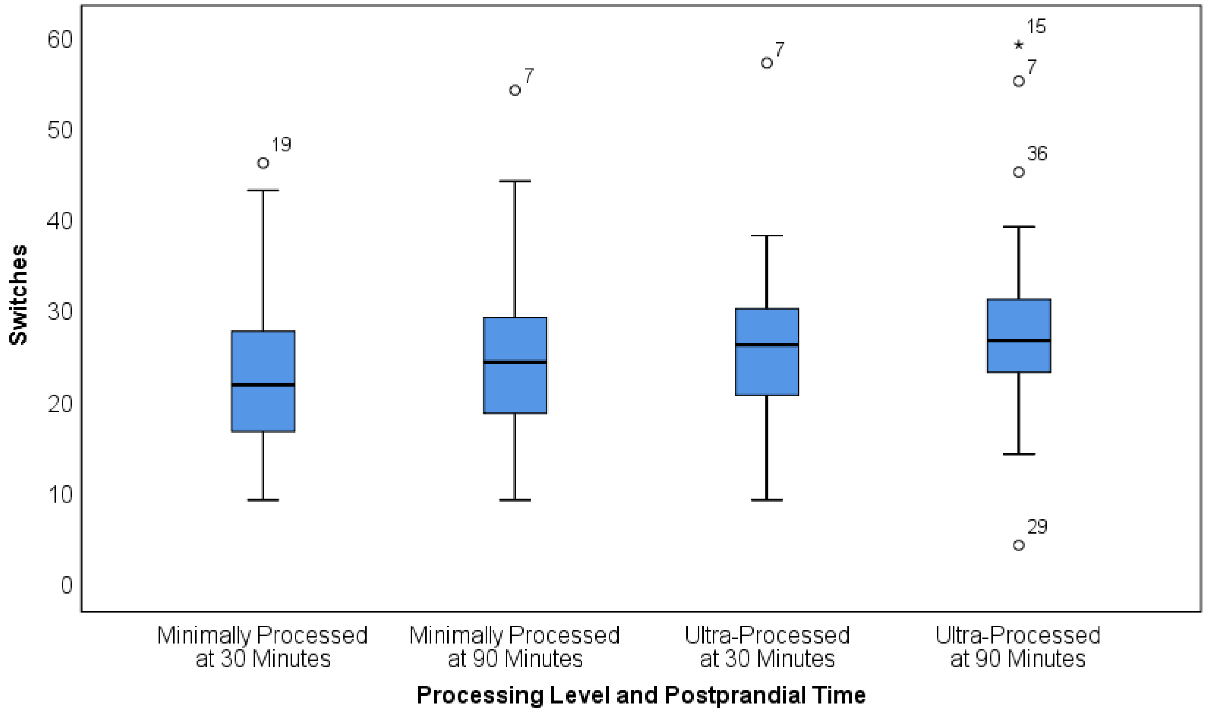


Phonemic Fluency Switches

Another measure related to phonemic fluency is the frequency of switches. Switches are transitions between clusters during a verbal fluency test. Figure 24 displays boxplots of the switches data in the phonemic fluency test.

Figure 24

Box Plots of Phonemic Fluency Switches



One to four outliers were present in each group. The highest switch mean was in the ultra-processed group at 90 minutes (*M* = 27.57, *SD* = 9.91), followed by the ultra-processed group at 30 minutes (*M* = 25.44, *SD* = 8.35), followed by the minimally processed group at 90 minutes (*M* = 24.67, *SD* = 8.78), followed by the minimally processed group at 30 minutes (*M* = 22.33, *SD* = 8.16).

A two-way within-subjects Analysis of Variance was conducted to evaluate the effect of processing level and postprandial time on phonemic fluency switches. The dependent variable was the number of switches with a minimum score of zero and no upper limit. The within-subjects factors were postprandial time with two levels (30 minutes and 90 minutes) and processing level with two levels (minimally processed and ultra-processed). The resulting test results are available in Table 16.

Table 16

ANOVA Results for Phonemic Fluency Switches

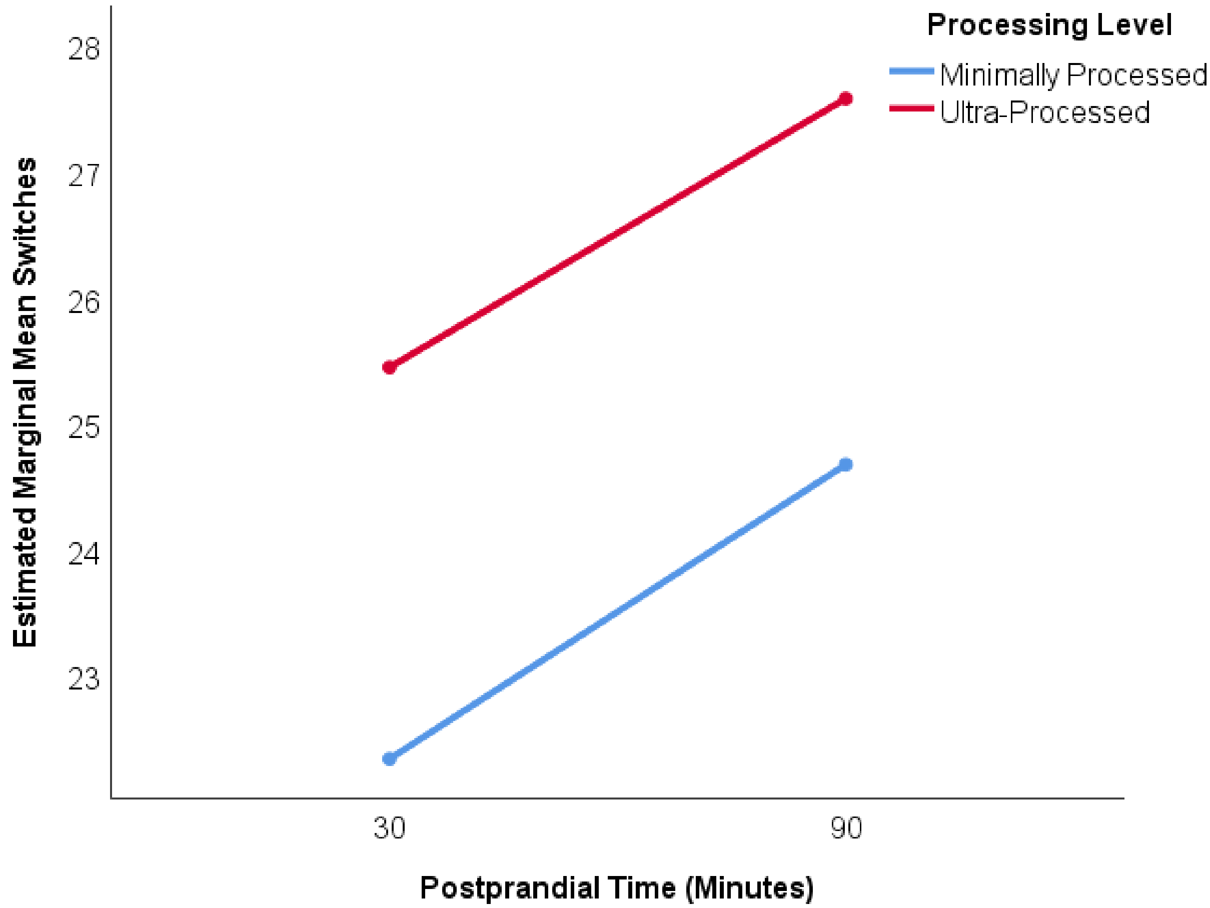
Source	Sum of Squares	*df*	Mean Square	*F*	*p*	η^2
P	361.62	1	361.62	11.60^{**}	<.01	.23
Error (P)	1,216.04	39	31.18			
T	199.72	1	199.72	6.87^{*}	.01	.15
Error (T)	1,134.53	39	29.09			
P * T	0.42	1	0.42	0.02	.90	<.01
Error (P * T)	930.77	39	23.87			

Note. ANOVA = Analysis of Variance; P = Processing Level; T = Postprandial Time.
$^{*}p < .05$. $^{**}p < .01$

The interaction between postprandial time and processing level was found to be nonsignificant, $F(1, 39) = 0.02$, $p = .90$, partial $\eta^2 < .01$. Therefore, follow-up tests for simple main effects were not conducted. The univariate test associated with the processing level main effect was significant, $F(1, 39) = 11.60$, $p < .01$, partial $\eta^2 = .23$. The univariate test associated with the postprandial time main effect was also significant, $F(1, 39) = 6.87$, $p = .01$, partial $\eta^2 = .15$. In summary, phonemic fluency switches were significantly greater in the ultra-processed group, compared to the minimally processed group, as well as at 90 minutes, compared to 30 minutes. The effect sizes are large, accounting for 23% and 15% of the variance in switches for processing level and postprandial time, respectively (Green & Salkind, 2017, p. 126). Both effects are visible in Figure 25.

Figure 25

Profile Plots of Phonemic Fluency Switches

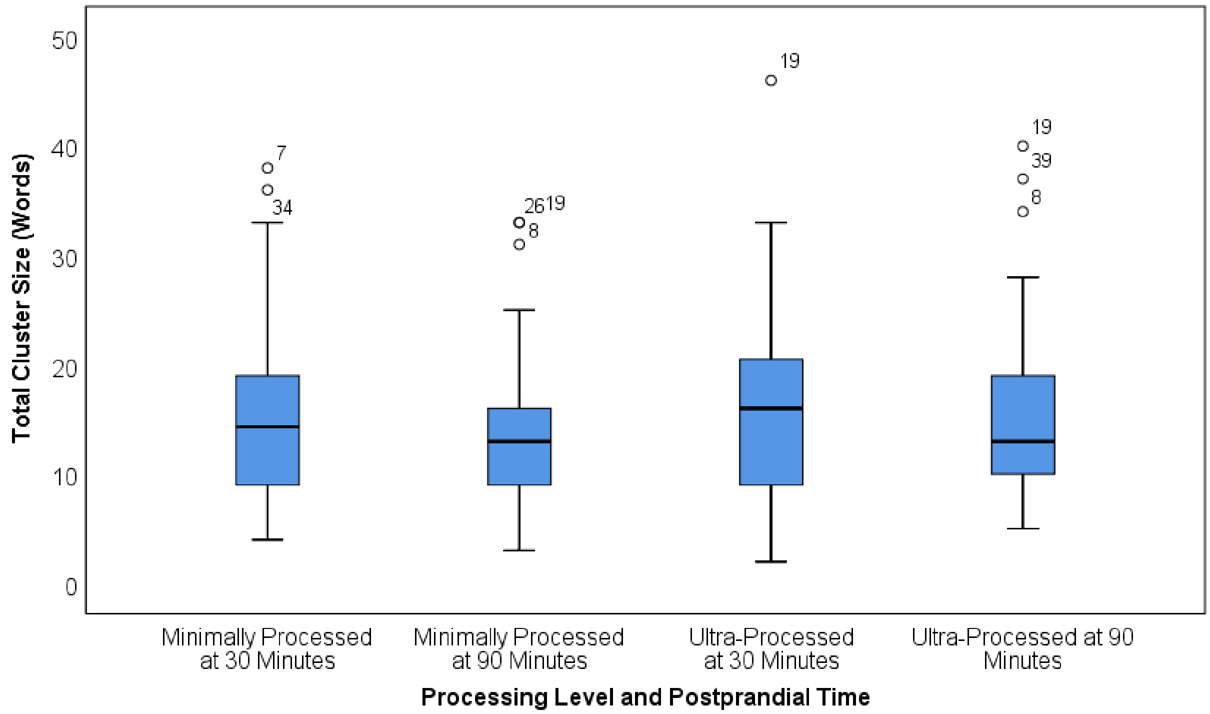


Phonemic Fluency Total Cluster Size

Another measure related to phonemic fluency is total cluster size. In verbal fluency tests, cluster size is the count of words in a cluster, starting with the second word in the cluster. Total cluster size is the sum of cluster sizes. Figure 26 displays boxplots of the total cluster size data in the phonemic fluency test.

Figure 26

Box Plots of Phonemic Fluency Total Cluster Size



One to three outliers were present in each group. The highest mean total cluster size was in the ultra-processed group at 30 minutes (M = 16.19, SD = 9.27), followed by the ultra-processed group at 90 minutes (M = 15.56, SD = 8.11), followed by the minimally processed group at 30 minutes (M = 14.79, SD = 8.31), followed by the minimally processed group at 90 minutes (M = 13.95, SD = 7.56).

A two-way within-subjects Analysis of Variance was conducted to evaluate the effect of processing level and postprandial time on phonemic fluency total cluster size. The dependent variable was total cluster size with a minimum of zero and no upper limit. The within-subjects factors were postprandial time with two levels (30 minutes and 90 minutes) and processing level with two levels (minimally processed and ultra-processed). The resulting test results are available in Table 17.

Table 17

ANOVA Results for Phonemic Fluency Total Cluster Size

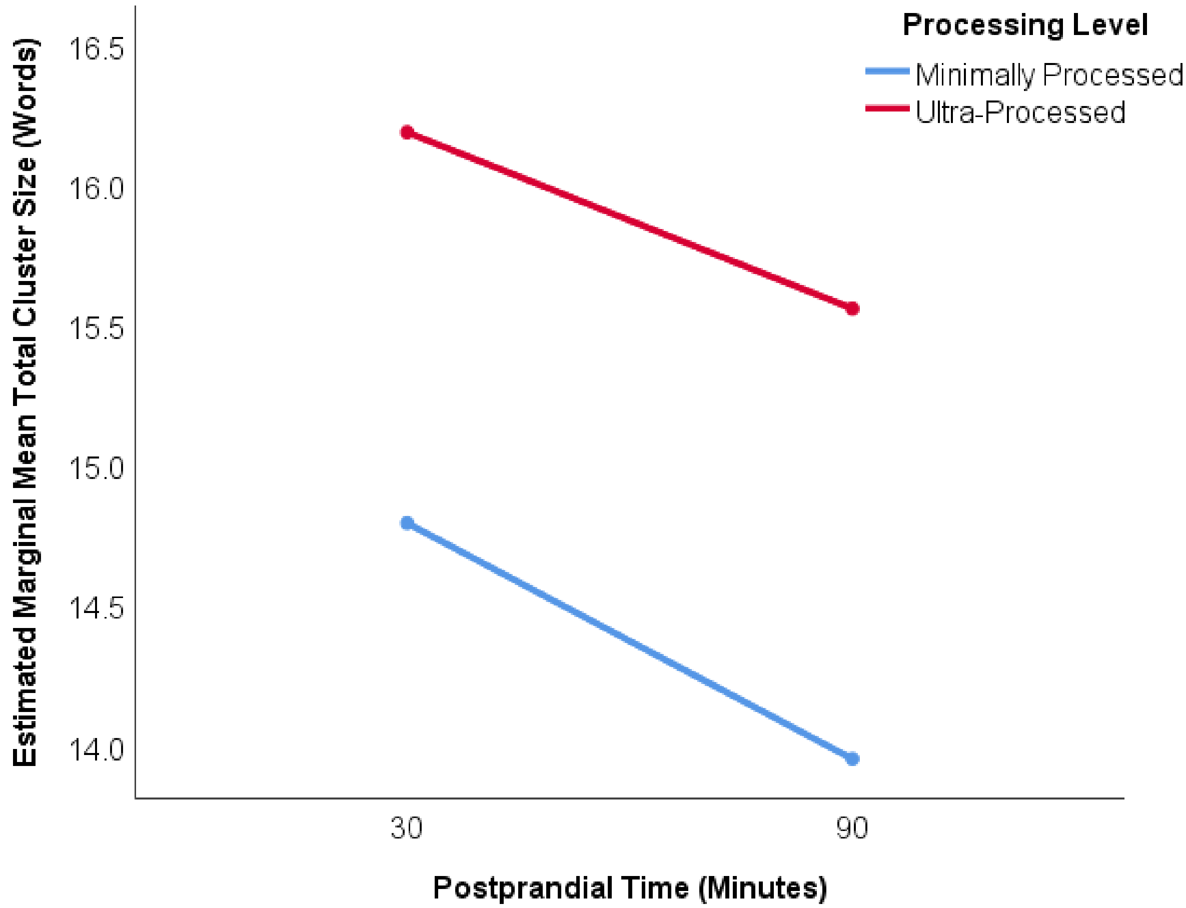
Source	Sum of Squares	*df*	Mean Square	*F*	*p*	η^2
P	90.38	1	90.38	2.49	.12	.06
Error (P)	1,418.28	39	36.37			
T	21.70	1	21.70	1.02	.32	.03
Error (T)	831.05	39	21.31			
P * T	0.45	1	0.45	0.02	.88	<.01
Error (P * T)	712.01	39	18.26			

Note. ANOVA = Analysis of Variance; P = Processing Level; T = Postprandial Time.
$^{*}p < .05$. $^{**}p < .01$

The interaction between postprandial time and processing level was found to be nonsignificant, $F(1, 39) = 0.02$, $p = .88$, partial $\eta^2 < .01$. Therefore, follow-up tests for simple main effects were not conducted. The univariate test associated with the processing level main effect was also nonsignificant, $F(1, 39) = 2.49$, $p = .12$, partial $\eta^2 = .06$. The univariate test associated with the postprandial time main effect was also nonsignificant, $F(1, 39) = 1.02$, $p = .32$, partial $\eta^2 = .03$. The effect sizes indicated that processing level and postprandial time accounted for 6% and 3% of the variance in total cluster size, respectively. These effect sizes were considered medium and small, respectively (Green & Salkind, 2017, p. 126). However, the impacts were not statistically significant. Both effects are visible in Figure 27.

Figure 27

Profile Plots of Phonemic Fluency Total Cluster Size

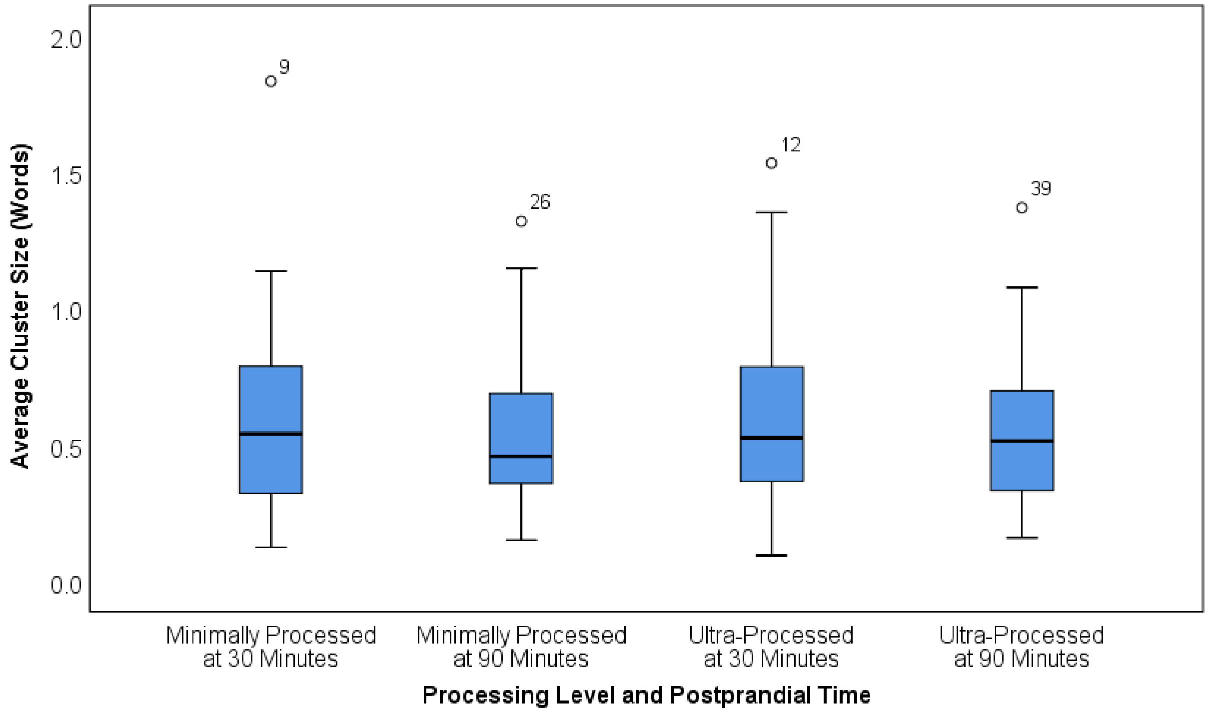


Phonemic Fluency Average Cluster Size

The final measure related to phonemic fluency is average cluster size. In verbal fluency tests, average cluster size is the total cluster size divided by the total number of clusters. Figure 28 displays boxplots of the average cluster size data in the phonemic fluency test.

Figure 28

Box Plots of Phonemic Fluency Average Cluster Size



One outlier was present in each group. The highest mean average cluster size was in the minimally processed group at 30 minutes (*M* = 0.60, *SD* = 0.33), followed by the ultra-processed group at 30 minutes (*M* = 0.59, *SD* = 0.33), followed by the ultra-processed group at 90 minutes (*M* = 0.54, *SD* = 0.26), followed by the minimally processed group at 90 minutes (*M* = 0.53, *SD* = 0.27).

A two-way within-subjects Analysis of Variance was conducted to evaluate the effect of processing level and postprandial time on phonemic fluency average cluster size. The dependent variable was average cluster size with a minimum of zero and no upper limit. The within-subjects factors were postprandial time with two levels (30 minutes and 90 minutes) and processing level with two levels (minimally processed and ultra-processed). The resulting test results are available in Table 18.

Table 18

ANOVA Results for Phonemic Fluency Average Cluster Size

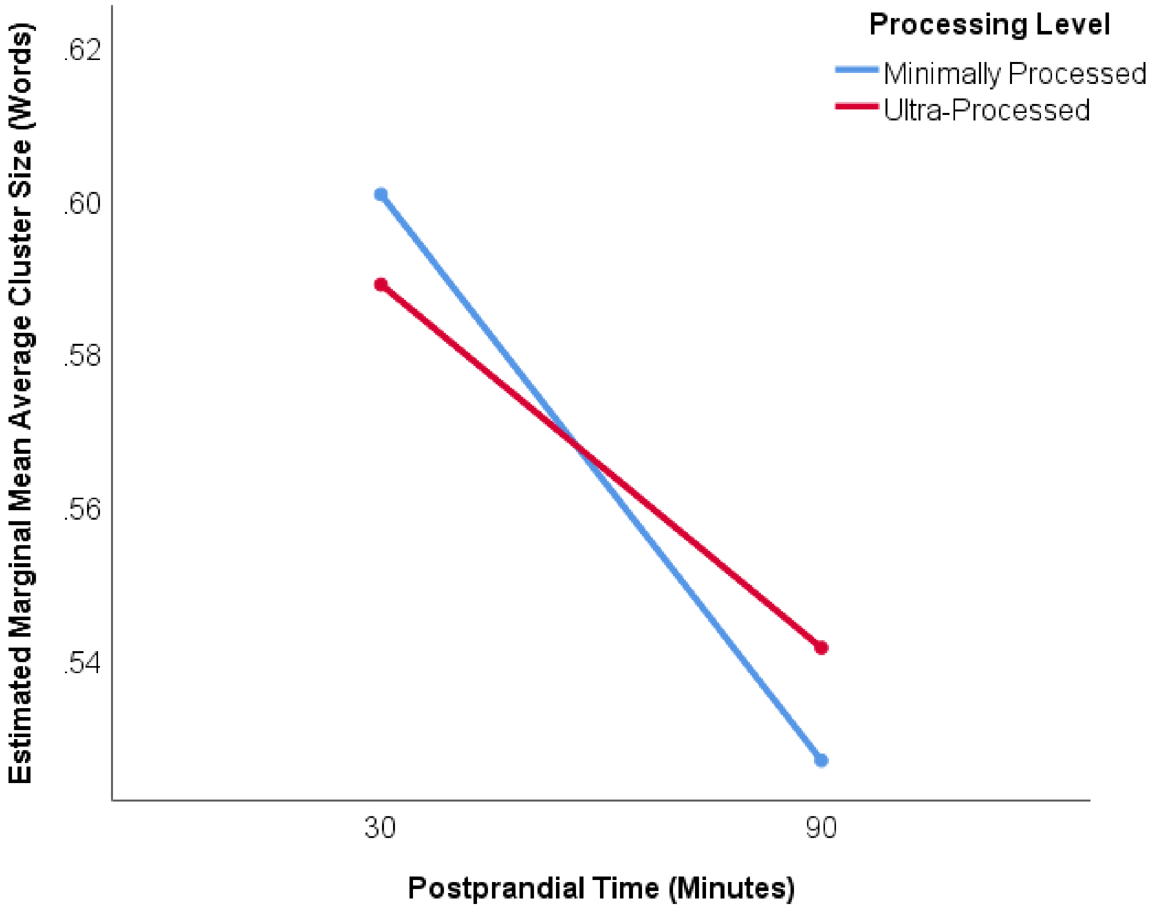
Source	Sum of Squares	*df*	Mean Square	*F*	*p*	η^2
P	<0.01	1	<0.01	<0.01	.98	<.01
Error (P)	3.55	39	0.09			
T	0.15	1	0.15	2.76	.10	.07
Error (T)	2.09	39	0.05			
P * T	0.01	1	0.01	0.11	.74	<.01
Error (P * T)	2.43	39	0.06			

Note. ANOVA = Analysis of Variance; P = Processing Level; T = Postprandial Time.
$^{*}p < .05$. $^{**}p < .01$

The interaction between postprandial time and processing level was found to be nonsignificant, $F(1, 39) = 0.11$, $p = .74$, partial $\eta^2 < .01$. Therefore, follow-up tests for simple main effects were not conducted. The univariate test associated with the processing level main effect was also nonsignificant, $F(1, 39) < 0.01$, $p = .98$, partial $\eta^2 < .01$. The univariate test associated with the postprandial time main effect was also nonsignificant, $F(1, 39) = 2.76$, $p = .10$, partial $\eta^2 = .07$. Postprandial time had a medium effect size, accounting for 7% of the variance in average cluster size; however, this effect was not statistically significant (Green & Salkind, 2017, p. 126). Estimated marginal means are visible in Figure 29.

Figure 29

Profile Plots of Phonemic Fluency Average Cluster Size



Hypotheses 7–9: Semantic Fluency Results

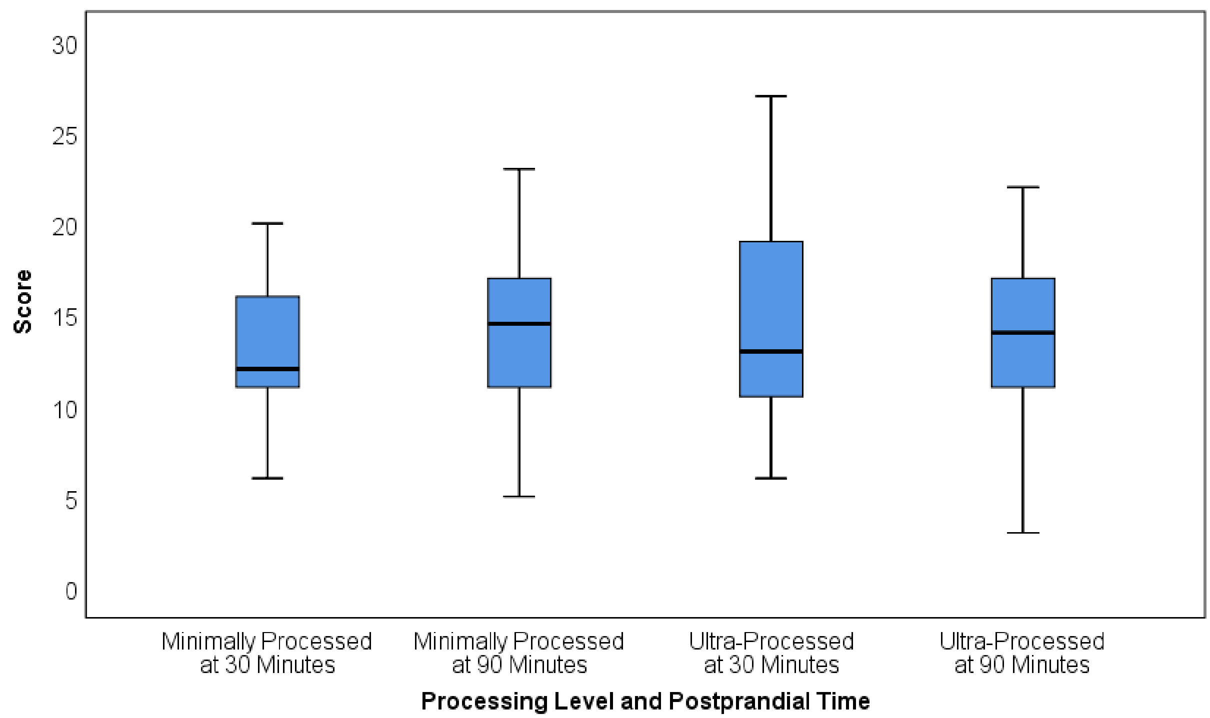
There are six specific measures related to semantic fluency. The primary measure of semantic fluency is semantic fluency score. Perseverations are repetitions of the same word in a given trial. Intrusions are incorrect words, including those that do not fit the category given. A cluster is a sequence of words that are examples of a common subcategory within the broader category of the test. Switches are the number of transitions between one cluster and the next. Cluster size is defined as the count of words in a given cluster, starting with the second word. Therefore, total cluster is the sum of all cluster sizes in a semantic fluency test. Average cluster size is defined as the total cluster size divided by the total number of clusters.

Semantic Fluency Score

The primary measure of semantic fluency is semantic fluency score. Semantic fluency score is the performance of one trial of a phonemic fluency test. In this trial, participants are asked to name as many words as possible in one minute that fit a certain category (e.g., animals). Figure 30 displays boxplots of the semantic fluency score data.

Figure 30

Box Plots of Semantic Fluency Score



No outliers were present in the data. The highest mean semantic fluency score was in the ultra-processed group at 30 minutes (*M* = 14.35, *SD* = 5.42), followed by the minimally processed group at 90 minutes (*M* = 14.29, *SD* = 4.36), followed by the ultra-processed group at 90 minutes (*M* = 13.80, *SD* = 4.63), followed by the minimally processed group at 30 minutes (*M* = 13.15, *SD* = 3.61).

A two-way within-subjects Analysis of Variance was conducted to evaluate the effect of processing level and postprandial time on semantic fluency score. The dependent variable was a

semantic fluency score with a minimum score of zero and no upper limit. The within-subjects factors were postprandial time with two levels (30 minutes and 90 minutes) and processing level with two levels (minimally processed and ultra-processed). The resulting test results are available in Table 19.

Table 19

ANOVA Results for Semantic Fluency Score

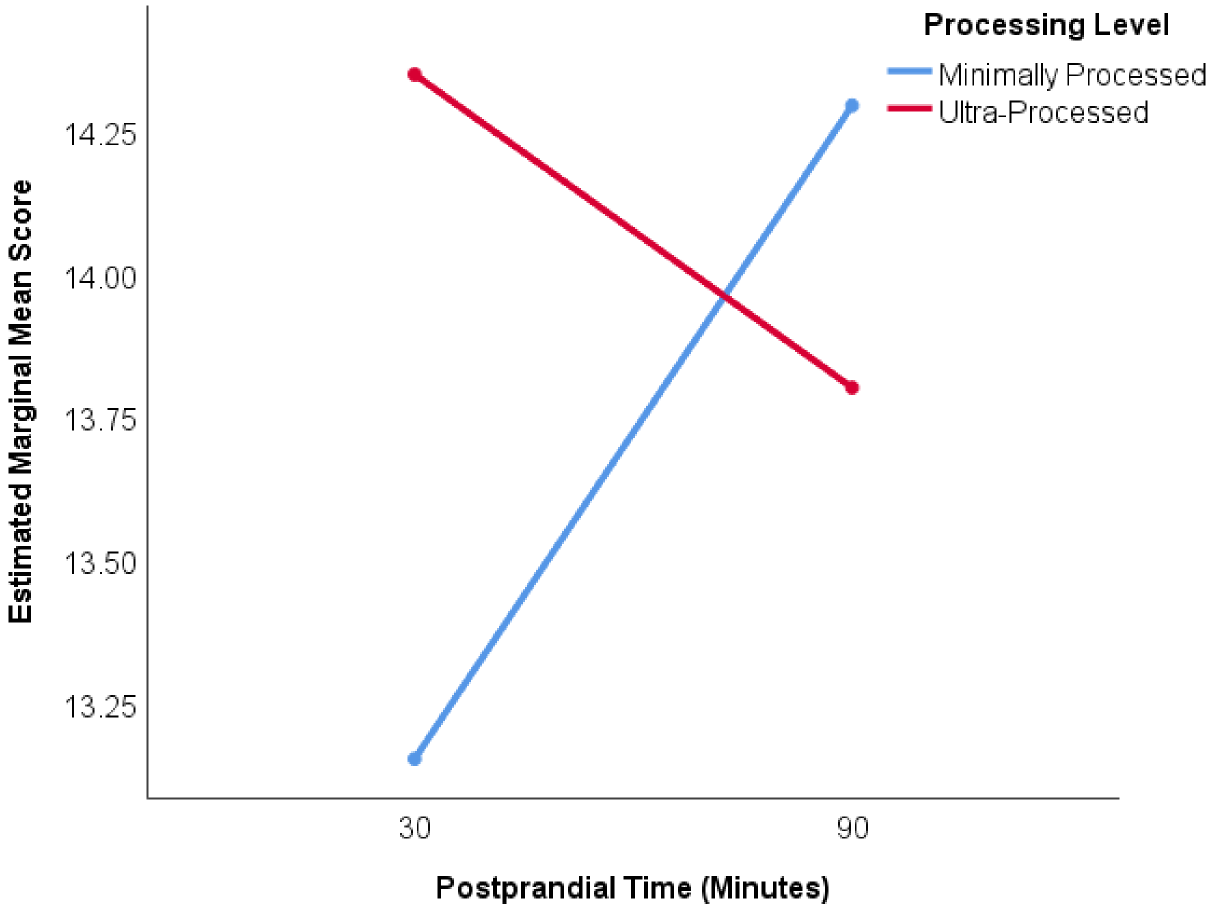
Source	Sum of Squares	*df*	Mean Square	*F*	*p*	η^2
P	4.96	1	4.96	0.46	.50	.01
Error (P)	416.58	39	10.68			
T	3.55	1	3.55	0.39	.54	.01
Error (T)	358.47	39	9.19			
P * T	28.65	1	28.65	1.14	.29	.03
Error (P * T)	981.61	39	25.17			

Note. ANOVA = Analysis of Variance; P = Processing Level; T = Postprandial Time.
$^{*}p < .05$. $^{**}p < .01$

The interaction between postprandial time and processing level was found to be nonsignificant, $F(1, 39) = 1.14$, $p = .29$, partial $\eta^2 = .03$. Therefore, follow-up tests for simple main effects were not conducted. The univariate test associated with the processing level main effect was nonsignificant, $F(1, 39) = 0.46$, $p = .50$, partial $\eta^2 = .01$. The univariate test associated with the postprandial time main effect was nonsignificant, $F(1, 39) = 0.39$, $p = .54$, partial $\eta^2 = .01$. Therefore, processing level and postprandial time did not significantly impact semantic fluency score. Estimated marginal means are visible in Figure 31.

Figure 31

Profile Plots of Semantic Fluency Score

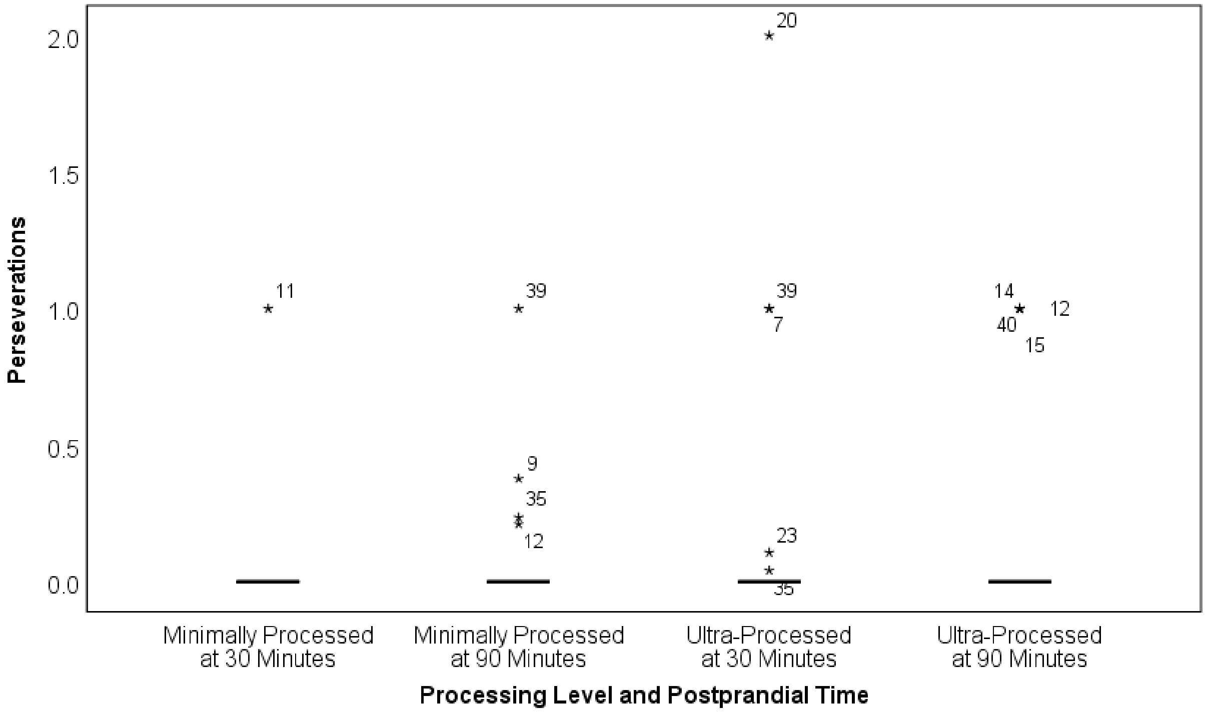


Semantic Fluency Perseverations

Another measure related to phonemic fluency is the count of perseverations. Perseverations are repeated words in a verbal fluency test. Figure 32 displays boxplots of the perseveration data in the semantic fluency test.

Figure 32

Box Plots of Semantic Fluency Perseverations



One to five outliers were present in each group. The highest perseveration mean was in the ultra-processed group at 30 minutes (M = 0.10, SD = 0.38) and 90 minutes (M = 0.10, SD = 0.30), followed by the minimally processed group at 90 minutes (M = 0.05, SD = 0.17), followed by the minimally processed group at 30 minutes (M = 0.03, SD = 0.16).

A two-way within-subjects Analysis of Variance was conducted to evaluate the effect of processing level and postprandial time on semantic fluency perseverations. The dependent variable was the number of perseverations with a minimum of zero and no upper limit. The within-subjects factors were postprandial time with two levels (30 minutes and 90 minutes) and processing level with two levels (minimally processed and ultra-processed). The resulting test results are available in Table 20.

Table 20

ANOVA Results for Semantic Fluency Perseverations

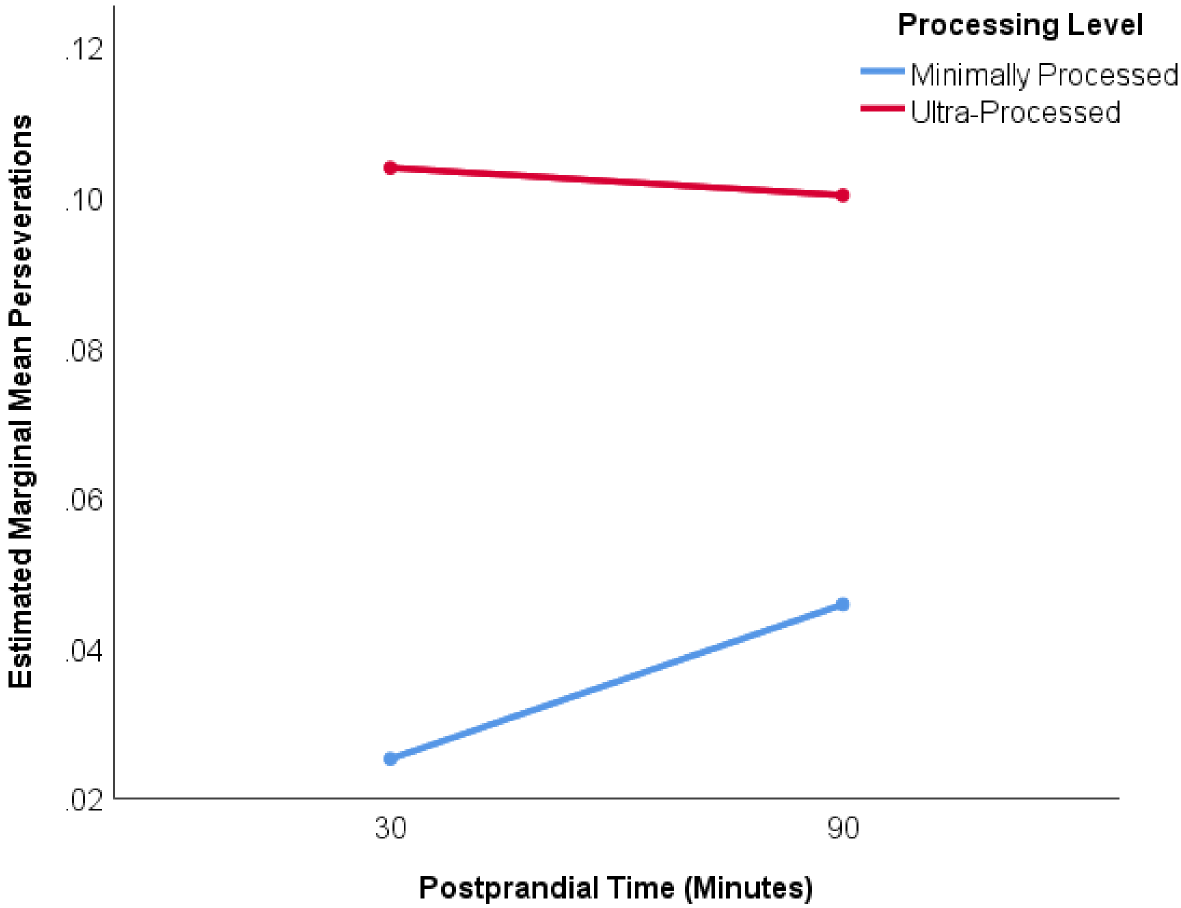
Source	Sum of Squares	*df*	Mean Square	*F*	*p*	η^2
P	.18	1	0.18	3.03	.09	.07
Error (P)	2.28	39	0.06			
T	<.01	1	<.01	0.04	.84	<.01
Error (T)	2.66	39	0.07			
P * T	0.01	1	0.01	0.07	.80	<.01
Error (P * T)	3.46	39	0.09			

Note. ANOVA = Analysis of Variance; P = Processing Level; T = Postprandial Time.
$^{*}p < .05$. $^{**}p < .01$

The interaction between postprandial time and processing level was found to be nonsignificant, $F(1, 39) = 0.07$, $p = .80$, partial $\eta^2 < .01$. Therefore, follow-up tests for simple main effects were not conducted. The univariate test associated with the processing level main effect was also nonsignificant, $F(1, 39) = 3.03$, $p = .09$, partial $\eta^2 = .07$. The univariate test associated with the postprandial time main effect was also nonsignificant, $F(1, 39) = 0.04$, $p = .84$, partial $\eta^2 < .01$. Processing level had a medium effect size, accounting for 7% of the variance in perseverations, although this effect did not reach statistical significance (Green & Salkind, 2017, p. 126). Estimated marginal means are visible in Figure 33.

Figure 33

Profile Plots of Semantic Fluency Perseverations

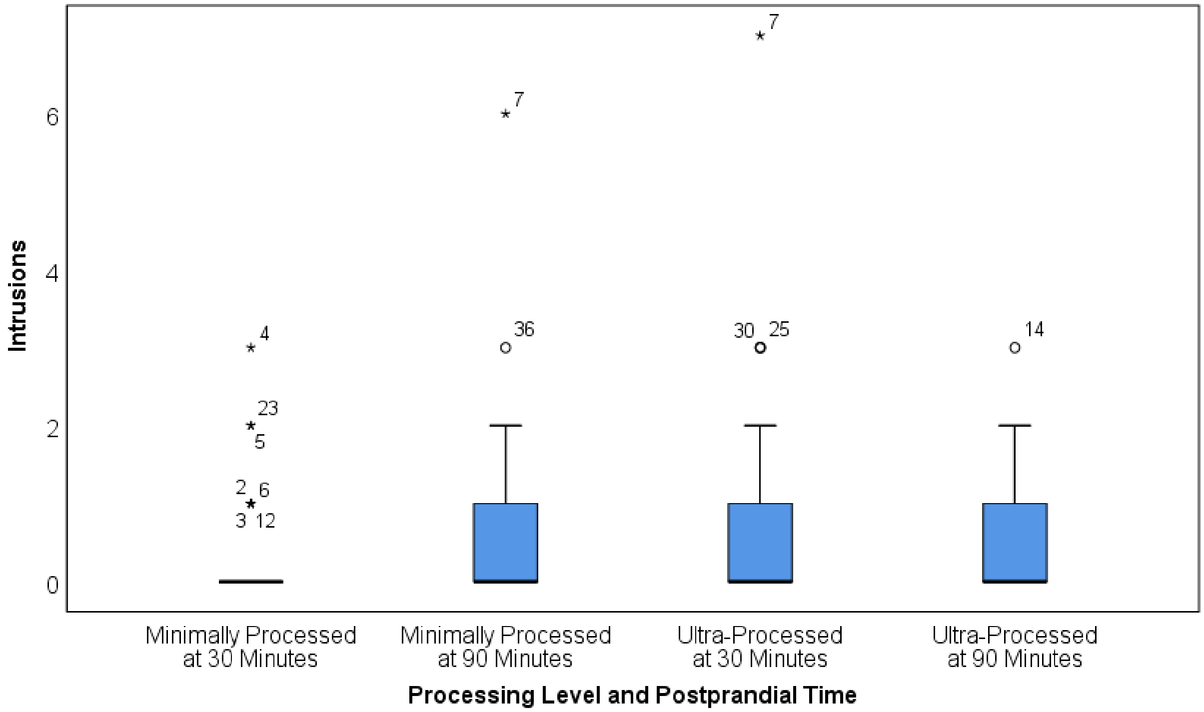


Semantic Fluency Intrusions

Another outcome related to semantic fluency is the count of intrusions. Intrusions are incorrect or invalid words in a verbal fluency test. Figure 34 displays boxplots of the intrusions data in the semantic fluency test.

Figure 34

Box Plots of Semantic Fluency Intrusions



One to seven outliers were present in each group. The highest intrusion mean was in the minimally processed group at 90 minutes (*M* = 0.77, *SD* = 1.17), followed by the ultra-processed group at 30 minutes (*M* = 0.69, *SD* = 1.37), followed by the ultra-processed group at 90 minutes (*M* = 0.45, *SD* = 0.82), followed by the minimally processed group at 30 minutes (*M* = 0.30, *SD* = 0.69).

A two-way within-subjects Analysis of Variance was conducted to evaluate the effect of processing level and postprandial time on semantic fluency intrusions. The dependent variable was semantic fluency intrusions with a minimum of zero and no upper limit. The within-subjects factors were postprandial time with two levels (30 minutes and 90 minutes) and processing level with two levels (minimally processed and ultra-processed). The resulting test results are available in Table 21.

Table 21

ANOVA Results for Semantic Fluency Intrusions

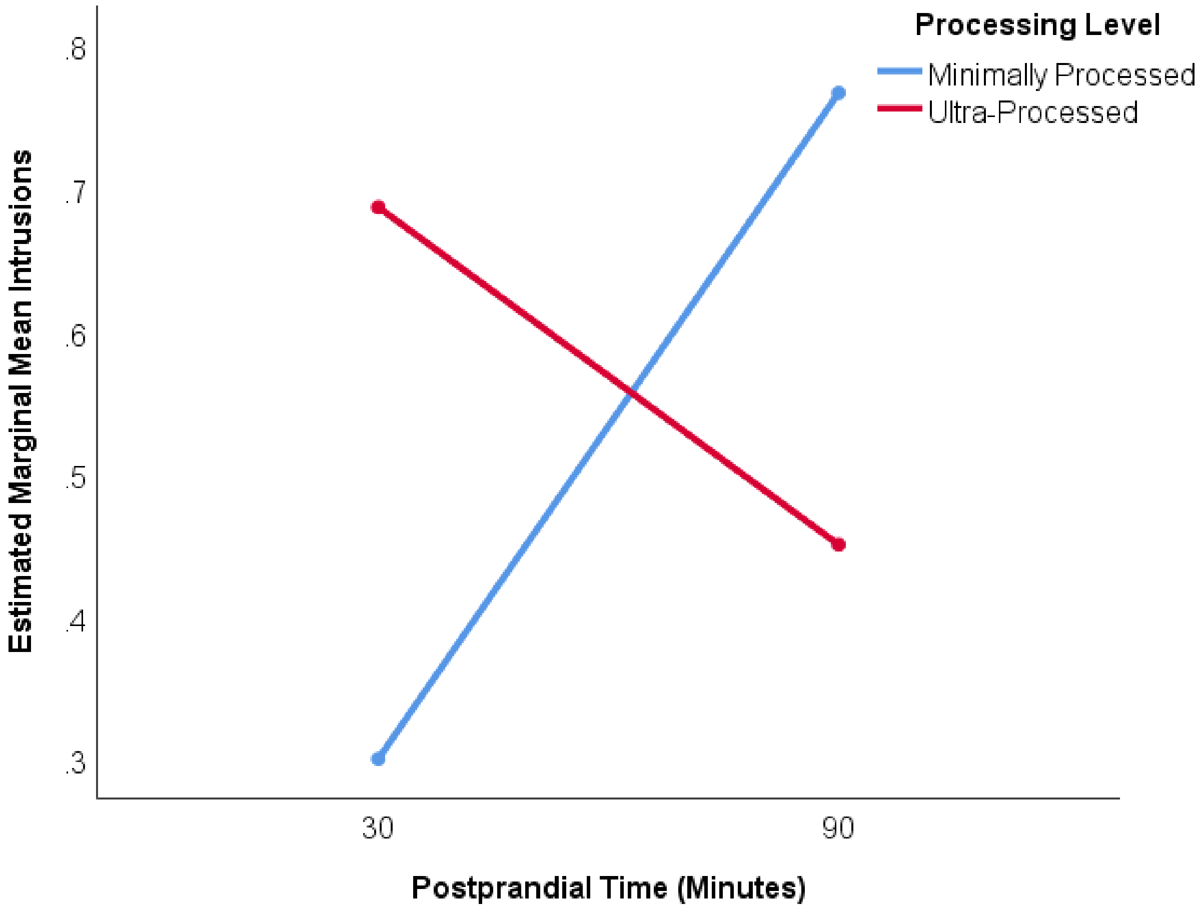
Source	Sum of Squares	*df*	Mean Square	*F*	*p*	η^2
P	0.05	1	0.05	0.07	.80	<.01
Error (P)	29.31	39	0.75			
T	0.53	1	0.53	0.76	.39	.02
Error (T)	27.30	39	0.70			
P * T	4.94	1	4.94	2.93	.09	.07
Error (P * T)	65.70	39	1.68			

Note. ANOVA = Analysis of Variance; P = Processing Level; T = Postprandial Time.
$^{*}p < .05$. $^{**}p < .01$

The interaction between postprandial time and processing level was found to be nonsignificant, $F(1, 39) = 2.93$, $p = .09$, partial $\eta^2 = .07$. Therefore, follow-up tests for simple main effects were not conducted. The univariate test associated with the processing level main effect was also nonsignificant, $F(1, 39) = 0.07$, $p = .80$, partial $\eta^2 < .01$. The univariate test associated with the postprandial time main effect was also nonsignificant, $F(1, 39) = 0.76$, $p = .39$, partial $\eta^2 = .02$. The interaction effect had a medium effect size, accounting for 7% of the variance in intrusions, although this effect did not reach statistical significance (Green & Salkind, 2017, p. 126). Estimated marginal means are visible in Figure 35.

Figure 35

Profile Plots of Semantic Fluency Intrusions

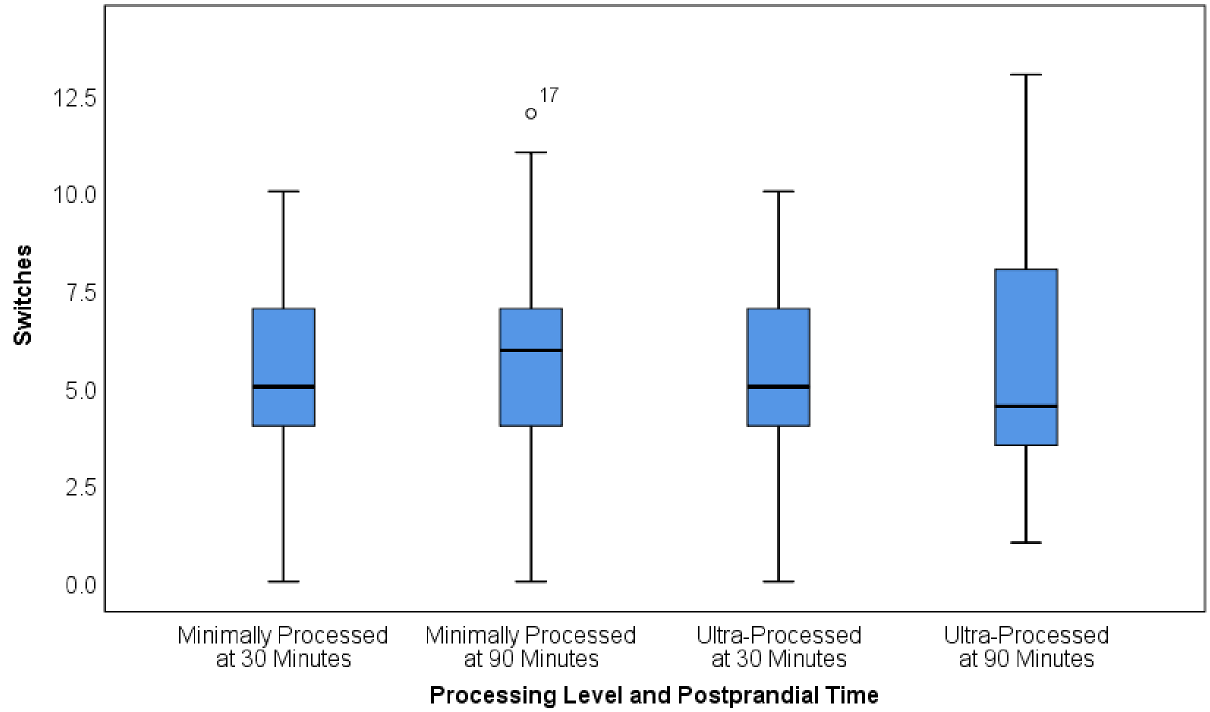


Semantic Fluency Switches

Another outcome related to semantic fluency is the frequency of switches. Switches are transitions between clusters during a verbal fluency test. Figure 36 displays boxplots of the switches data in the semantic fluency test.

Figure 36

Box Plots of Semantic Fluency Switches



One outlier was present in the data. The highest mean number of switches was in the minimally processed group at 90 minutes (M = 5.61, SD = 2.72), followed by the minimally processed group at 30 minutes (M = 5.47, SD = 2.34), followed by the ultra-processed group at 90 minutes (M = 5.40, SD = 2.90), followed by the ultra-processed group at 30 minutes (M = 5.02, SD = 2.53).

A two-way within-subjects Analysis of Variance was conducted to evaluate the effect of processing level and postprandial time on semantic fluency switches. The dependent variable was the number of switches with a minimum of zero and no upper limit. The within-subjects factors were postprandial time with two levels (30 minutes and 90 minutes) and processing level with two levels (minimally processed and ultra-processed). The resulting test results are available in Table 22.

Table 22

ANOVA Results for Semantic Fluency Switches

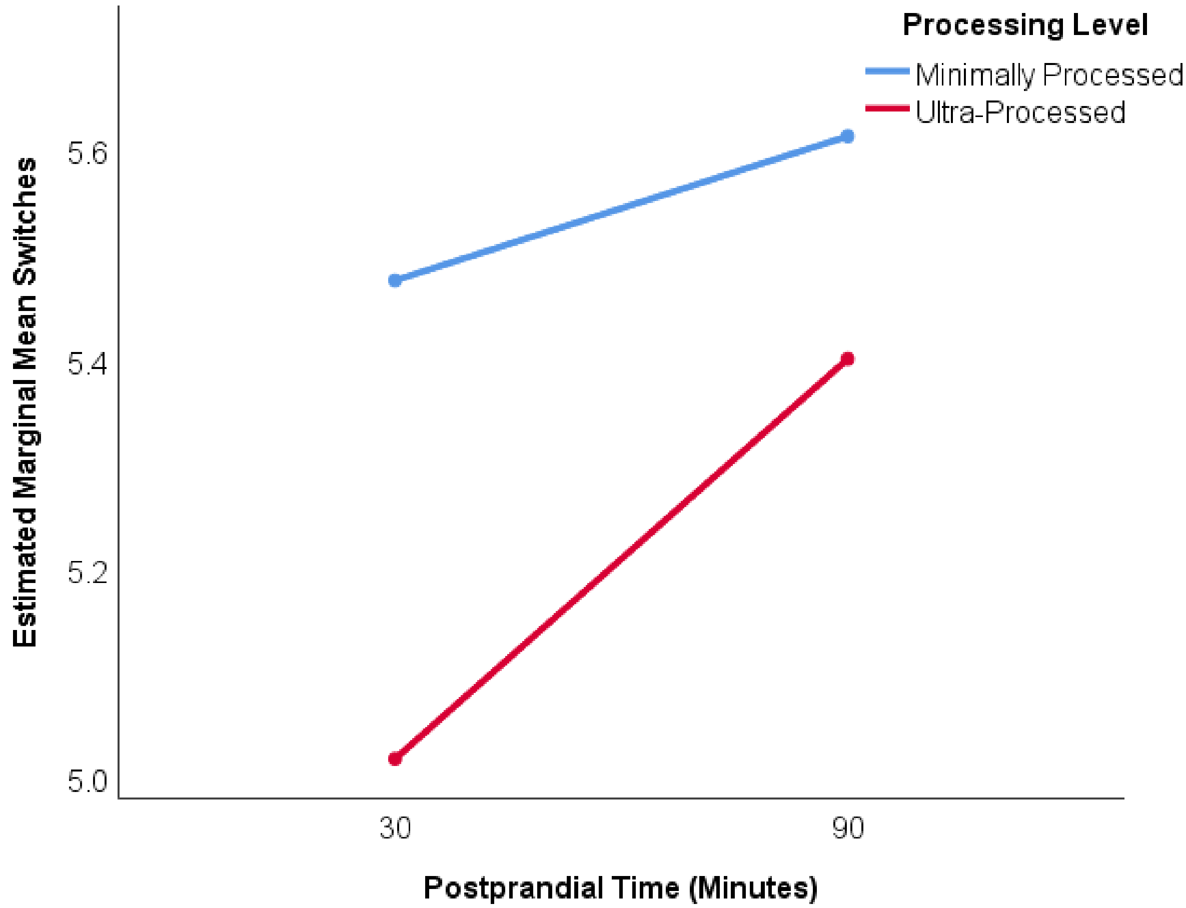
Source	Sum of Squares	*df*	Mean Square	*F*	*p*	η^2
P	4.49	1	4.49	0.56	.46	.01
Error (P)	313.73	39	8.04			
T	2.71	1	2.71	0.45	.51	.01
Error (T)	233.39	39	5.98			
P * T	0.60	1	0.60	0.24	.63	.01
Error (P * T)	98.56	39	2.53			

Note. ANOVA = Analysis of Variance; P = Processing Level; T = Postprandial Time.
$^{*}p < .05$. $^{**}p < .01$

The interaction between postprandial time and processing level was found to be nonsignificant, $F(1, 39) = 0.24$, $p = .63$, partial $\eta^2 = .01$. Therefore, follow-up tests for simple main effects were not conducted. The univariate test associated with the processing level main effect was also nonsignificant, $F(1, 39) = .56$, $p = .46$, partial $\eta^2 = .01$. The univariate test associated with the postprandial time main effect was also nonsignificant, $F(1, 39) = 0.45$, $p = .51$, partial $\eta^2 = .01$. Estimated marginal means are visible in Figure 37.

Figure 37

Profile Plots of Semantic Fluency Switches

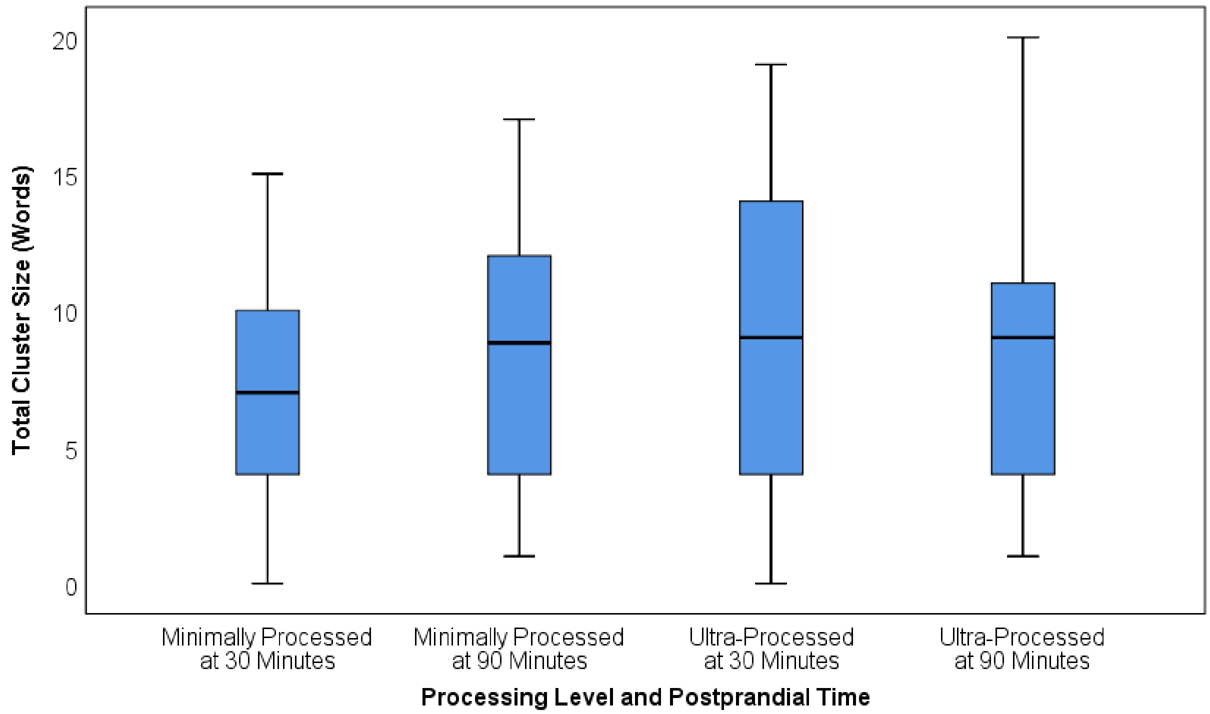


Semantic Fluency Total Cluster Size

Another outcome related to semantic fluency is total cluster size. In verbal fluency tests, cluster size is the count of words in a cluster, starting with the second word in the cluster. Total cluster size is the sum of cluster sizes. Figure 38 displays boxplots of the total cluster size data in the semantic fluency test.

Figure 38

Box Plots of Semantic Fluency Total Cluster Size



No outliers were present in the data. The highest mean total cluster size was in the ultra-processed group at 30 minutes (*M* = .08, *SD* = 5.38), followed by the minimally processed group at 90 minutes (*M* = 8.34, *SD* = 4.32), followed by the ultra-processed group at 90 minutes (*M* = 7.88, *SD* = 4.57), followed by the minimally processed group at 30 minutes (*M* = 7.00, *SD* = 3.93).

A two-way within-subjects Analysis of Variance was conducted to evaluate the effect of processing level and postprandial time on semantic fluency total cluster size. The dependent variable was total cluster size with a minimum of zero and no upper limit. The within-subjects factors were postprandial time with two levels (30 minutes and 90 minutes) and processing level with two levels (minimally processed and ultra-processed). The resulting test results are available in Table 23.

Table 23

ANOVA Results for Semantic Fluency Total Cluster Size

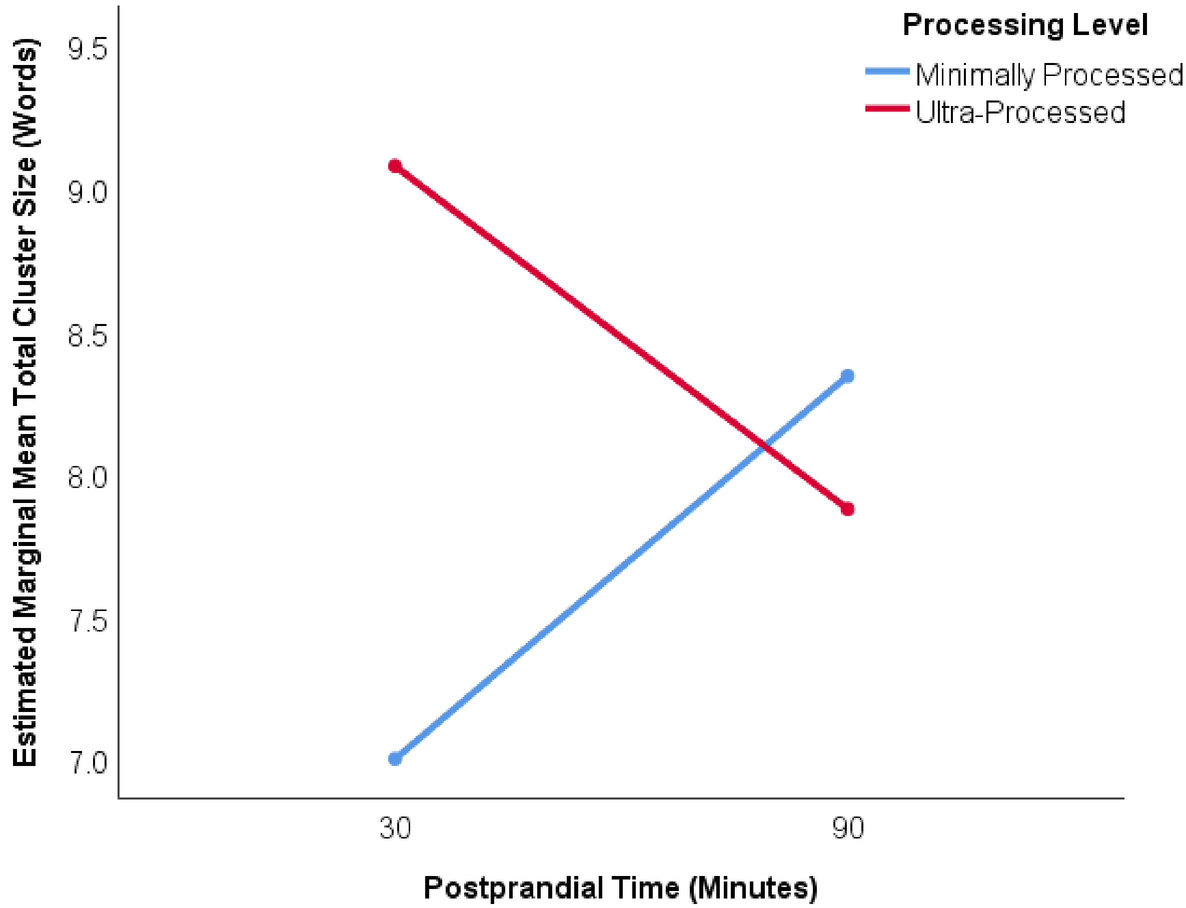
Source	Sum of Squares	*df*	Mean Square	*F*	*p*	η^2
P	25.92	1	25.92	2.63	.11	.06
Error (P)	385.05	39	9.87			
T	0.20	1	0.20	0.01	.90	<.01
Error (T)	510.08	39	13.08			
P * T	64.63	1	64.63	1.68	.20	.04
Error (P * T)	1,496.31	39	38.37			

Note. ANOVA = Analysis of Variance; P = Processing Level; T = Postprandial Time.
$^{*}p < .05$. $^{**}p < .01$

The interaction between postprandial time and processing level was found to be nonsignificant, $F(1, 39) = 1.68$, $p = .20$, partial $\eta^2 = .04$. Therefore, follow-up tests for simple main effects were not conducted. The univariate test associated with the processing level main effect was also nonsignificant, $F(1, 39) = 2.63$, $p = .11$, partial $\eta^2 = .06$. The univariate test associated with the postprandial time main effect was also nonsignificant, $F(1, 39) = 0.01$, $p = .90$, partial $\eta^2 < .01$. Processing level had a medium effect size, accounting for 6% of the variance in total cluster size (Green & Salkind, 2017, p. 126). However, this effect did not reach statistical significance. Estimated marginal means are visible in Figure 39.

Figure 39

Profile Plots of Semantic Fluency Total Cluster Size

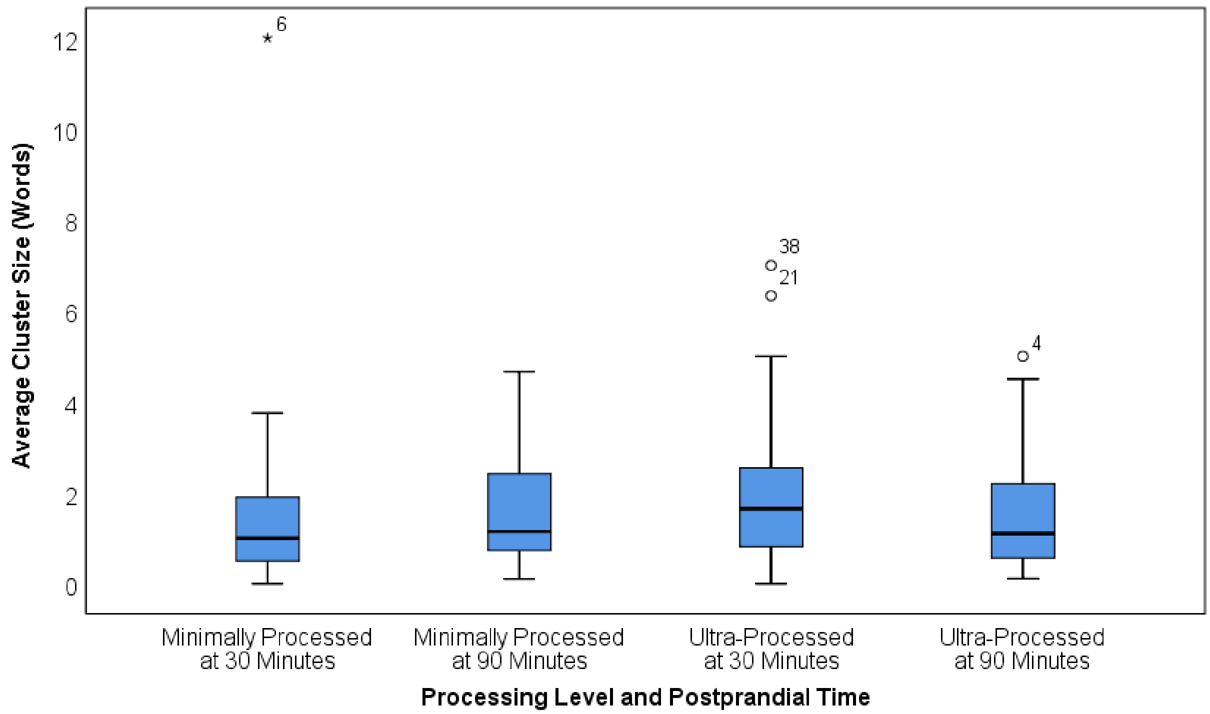


Semantic Fluency Average Cluster Size

The final measure related to semantic fluency is average cluster size. In verbal fluency tests, average cluster size is the total cluster size divided by the total number of clusters. Figure 40 displays boxplots of the average cluster size data in the semantic fluency test.

Figure 40

Box Plots of Semantic Fluency Average Cluster Size



Three outliers were present in the data. The highest mean average cluster size was in the ultra-processed group at 30 minutes (*M* = 1.94, *SD* = 1.60), followed by the minimally processed group at 90 minutes (*M* = 1.65, *SD* = 1.24), followed by the ultra-processed group at 90 minutes (*M* = 1.58, *SD* = 1.32), followed by the minimally processed group at 30 minutes (*M* = 1.51, *SD* = 1.94).

A two-way within-subjects Analysis of Variance was conducted to evaluate the effect of processing level and postprandial time on semantic fluency average cluster size. The dependent variable was average cluster size with a minimum of zero and no upper limit. The within-subjects factors were postprandial time with two levels (30 minutes and 90 minutes) and processing level with two levels (minimally processed and ultra-processed). The resulting test results are available in Table 24.

Table 24

ANOVA Results for Semantic Fluency Average Cluster Size

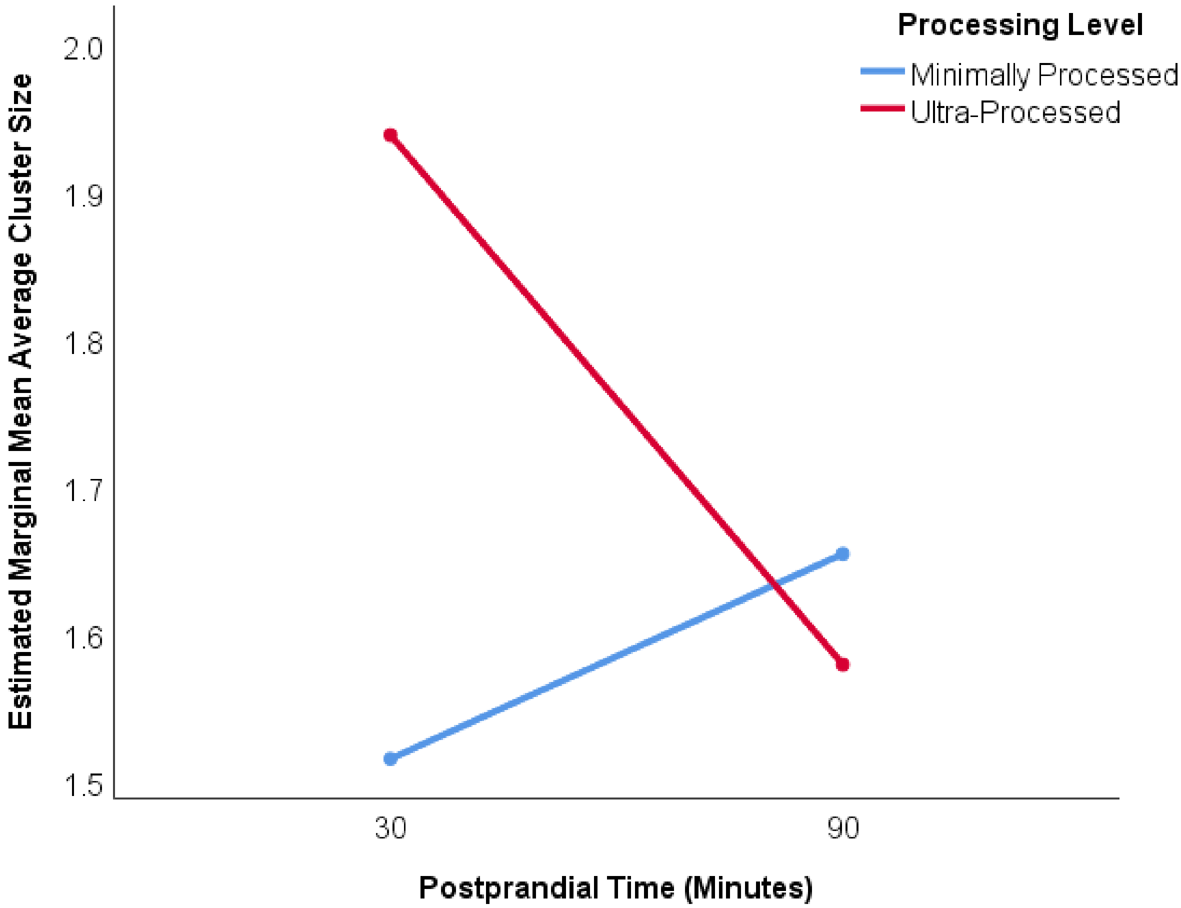
Source	Sum of Squares	*df*	Mean Square	*F*	*p*	η^2
P	1.22	1	1.22	0.57	.46	.01
Error (P)	83.69	39	2.15			
T	0.49	1	0.49	0.32	.58	.01
Error (T)	59.75	39	1.53			
P * T	2.49	1	2.49	0.87	.36	.02
Error (P * T)	111.83	39	2.87			

Note. ANOVA = Analysis of Variance; P = Processing Level; T = Postprandial Time.
$^{*}p < .05$. $^{**}p < .01$

The interaction between postprandial time and processing level was found to be nonsignificant, $F(1, 39) = 0.87$, $p = .36$, partial $\eta^2 = .02$. Therefore, follow-up tests for simple main effects were not conducted. The univariate test associated with the processing level main effect was also nonsignificant, $F(1, 39) = 0.57$, $p = .46$, partial $\eta^2 = .01$. The univariate test associated with the postprandial time main effect was also nonsignificant, $F(1, 39) = 0.32$, $p = .58$, partial $\eta^2 = .01$. Estimated marginal means are visible in Figure 41.

Figure 41

Profile Plots of Semantic Fluency Average Cluster Size



Chapter Summary

This research was designed to assess the causal impact of processing level of food consumed and postprandial time on verbal fluency and learning. Processing level of food consumed has two levels: minimally processed and ultra-processed. Postprandial time also has two levels: 30 minutes and 90 minutes. A summary of key results is organized by hypotheses below.

Hypotheses H1–H3 related to verbal learning. The primary measure was total recall score, but seven additional measures related to verbal learning include immediate memory, delayed recall, recognition, interference list score, retention, proactive interference, and

retroactive interference. Regarding hypothesis H1, it was determined that there was no statistically significant relationship between processing level of food consumed and immediate memory, retention, proactive interference, or retroactive interference. However, there was statistically significant improvement in total recall, interference list score, delayed recall, and recognition with the minimally processed meal, compared to the ultra-processed meal. Regarding hypothesis H2, there was no statistically significant relationship between postprandial time and interference list score. However, there was statistically significant improvement in total recall, immediate memory, delayed recall, recognition, retention, and retroactive interference at 30 minutes, as opposed to 90 minutes. On the contrary, there was a statistically significant improvement in proactive interference at 90 minutes, compared to 30 minutes. Regarding hypothesis H3, there were no statistically significant interactions between postprandial time and processing level of food consumed on any measures of verbal learning.

Hypotheses H4–H6 relate to phonemic fluency. The primary measure was phonemic fluency score, but five additional measures related to phonemic fluency include perseverations, intrusions, switches, total cluster size, and average cluster size. Regarding hypothesis H4, there was no statistically significant relationship between processing level of food consumed and perseverations, intrusions, total cluster size, or average cluster size. However, those consuming the ultra-processed meal had significantly higher phonemic fluency scores, compared to those eating the minimally processed meal. Similarly, the ultra-processed group demonstrated a significantly higher frequency of switches when conducting this test, compared to the minimally processed group. Regarding hypothesis H5, there was no statistically significant relationship between postprandial time and perseverations, intrusions, total cluster size, or average cluster size. However, there was a statistically significant improvement in phonemic fluency score at 90 minutes, compared to 30 minutes. There was also a significantly higher frequency of switches at

90 minutes, as opposed to 30 minutes. Regarding hypothesis H6, there were no statistically significant interactions between postprandial time and processing level of food consumed on phonemic fluency score, perseverations, switches, total cluster size, or average cluster size. However, there was a statistically significant interaction between postprandial time and processing level of food consumed on intrusions. For the minimally processed group, intrusions decreased significantly from 30 minutes to 90 minutes.

Hypothesis H7-H9 related to semantic fluency. The primary measure was semantic fluency score, but five additional measures related to semantic fluency include perseverations, intrusions, switches, total cluster size, and average cluster size. Regarding hypothesis H7, there were no statistically significant relationships between processing level of food consumed and any measures of semantic fluency. Regarding hypothesis H8, there were also no statistically significant relationships between postprandial time and any measures of semantic fluency. Regarding hypothesis H9, there were no statistically significant interactions between postprandial time and processing level of food consumed on measures of semantic fluency.

Chapter IV began with a description of the sample, followed by detailed documentation of descriptive and inferential statistics related to all twenty measures of the three main dependent variables. Chapter V will expand on these findings through a discussion of their connections with scholarly literature, limitations, application of Maslow's theory of needs, and practical application. It will also detail implications and recommendations for future research.

Chapter V. Conclusions and Recommendations

Ultra-processed food consumption is increasing on a global scale (Baker et al., 2020; Pagliai et al., 2021; Shim et al., 2021), prompting concerns about physical health (Afshin et al., 2019; Elizabeth et al., 2020), mental health (Coletro et al., 2022; Lane et al., 2021; Mesas et al., 2022), academic outcomes (Anderson et al., 2018; Blum et al., 2022), and cognition (Gonçalves et al., 2023; Melo et al., 2022; Weinstein et al., 2023). The United States has one of the highest, if not the highest, rates of ultra-processed food consumption in the world with roughly 60% of total calories consumed in the form of ultra-processed food (Lane et al., 2021). College students may consume an even greater proportion of their meals from ultra-processed food, compared to the national average (Martínez Steele et al., 2016). Quasi-experimental and correlational studies have suggested the possibility of a causal link between ultra-processed food consumption and cognition (Akbaraly et al., 2009; Anderson et al., 2018; Cardoso et al., 2022; Gonçalves et al., 2023; Melo et al., 2022; Ozawa et al., 2017; Pilato et al., 2020; Torres et al., 2012; Weinstein et al., 2023). However, these relationships have never previously been put to the test through a strong experimental design.

Therefore, this study was conducted to assess the previously unknown causal impact of processing level of food consumed and postprandial time on two aspects of cognition, verbal learning and verbal fluency. Forty college students participated in a randomized controlled trial comparing a minimally processed breakfast of whole-wheat crackers, minimally processed blueberry jelly, and oranges with an ultra-processed breakfast of blueberry toaster pastries and ultra-processed orange juice. Verbal learning, phonemic fluency, and semantic fluency were assessed 30 minutes and 90 minutes after the start of the meal. This study used two-way repeated-measures ANOVA to determine the significance and effect size of main effects and interactions.

Research Findings

The focus of this research was to answer the question, "What is the causal impact of processing level of food consumed (ultra-processed vs. minimally processed) and postprandial time (30 minutes vs. 90 minutes) on verbal fluency and learning?" Previous authors have suggested that it may take years of dietary adherence in order to observe significant dietary impacts on cognition (Krivanek et al., 2021). Therefore, it is noteworthy that this study resulted in 16 distinct statistically significant differences, based on single meal change. The directions of beneficial, statistically significant main effects are summarized in Table 25.

Table 25

Beneficial Main Effect Directions (η^2)

	Minimally Processed	**Ultra-Processed**	**30 Minutes**	**90 Minutes**
Verbal Learning				
Total Recall	↑ (.09)		↑ (.31)	
Immediate Memory			↑ (.30)	
Delayed Recall	↑ (.10)		↑ (.34)	
Recognition	↑ (.18)		↑ (.34)	
Interference List Score	↑ (.09)			
Retention			↑ (.28)	
Proactive Interference				↓ (.19)
Retroactive Interference			↓ (.10)	
Phonemic Fluency				
Phonemic Fluency Score		↑ (.39)		↑ (.10)
Intrusions				↓[a] (.17)
Switches		↑ (.23)		↑ (.15)

Note. ↑ = increase in outcome measure; ↓ = decrease in outcome measure.
[a] For minimally processed group only.

According to the data, food processing level did not impact semantic fluency. In the context of phonemic fluency, ultra-processed food consumption increased the number of switches and phonemic fluency score. However, minimally processed food caused improvement

in four measures of verbal learning: total recall, interference list score, delayed recall, and recognition.

Postprandial time also had several statistically significant impacts on cognitive outcomes. Although there were no significant relationships with semantic fluency, there were significant improvements in phonemic fluency score, phonemic fluency switches, and verbal learning proactive interference at 90 minutes, compared to 30 minutes. Higher postprandial time also resulted in fewer intrusions on a phonemic fluency test for the minimally processed group only. However, six measures of verbal learning showed a decline in performance from 30 minutes to 90 minutes. These included total recall, immediate memory, delayed recall, recognition, retention, and retroactive interference.

Connection and Contribution to Literature

This study made several unique contributions to the literature. These contributions included those related to the concepts studied, the study's nutritional framework, and its experimental design. This section also shares contributions to the literature on verbal learning and verbal fluency. Finally, this section includes contributions to Maslow's theory of needs.

Concepts Studied

Regarding concepts studied, previous researchers have recommended additional studies of the impact of diet on academic outcomes (Galioto & Spitznagel, 2016; Martin, 2022). Several have specifically requested future studies of the impact of processing level on mental health and cognition (Kent, Charlton, Netzel & Fanning, 2017; Gauci, 2022; Gonçalves et al., 2022; Lane et al., 2021; Na et al., 2022; Weinstein et al., 2022). Furthermore, several authors argued that the majority of research on cognition and diet has involved older adults, so more research is needed on young adults (Gauci, 2022; Peltzer & Pengpid, 2015; Pilato et al., 2020; Willis, 2021). Pilato et al., (2020) describe a "dearth of literature examining specific areas of neuropsychological

functioning in this age group," arguing that neuropsychological tests are more desirable than grades or test scores due to their ability to point toward specific cognitive functions (p. 6).

Nutritional Framework

Another way that this study contributed to the literature was the lens through which nutrition was viewed. This study approached nutrition from the framework of food synergy, as opposed to nutrient reductionism. As such, it joined a growing movement in the literature to examine nutrition at the broader level of foods, food types, and patterns of food consumption (Berding et al., 2021; Bernice, 2021; Fardet & Rock, 2018; Kent, Charlton, Netzel & Fanning, 2017; Jacobs et al., 2011; Jacobs & Steffen, 2003; Livingston et al., 2020; Lunsford, 2022; Margină et al., 2020; Messina et al., 2001; Pistollato & Battino, 2014; Tapsell et al., 2016). The Nova system of food processing level classification is consistent with this broader framework (Martinez-Perez et al., 2021).

Experimental Design

This study also contributed to the literature based on its strong experimental design. In the context of nutrition and academic outcomes, previous researchers have recommended intervention studies (Berding et al., 2021; Marx et al., 2021; Pfreundschuh, 2022; Sung et al., 2021), randomized controlled trials of processing level and cognition (de Miranda et al., 2021; Gauci, 2022; Gonçalves et al., 2022; Krivanek et al., 2021), and repeated-measures studies of ultra-processed food (Mesas et al., 2022). Specific design features such as randomization, counterbalancing, blinded data collection and grading, and repeated-measures design allowed participants to act as their own controls and eliminated confounding sources of variation. Because meals were provided by the researcher, the results were not impaired by a participant's dietary self-reporting bias (Andrade et al., 2021; Cardoso et al., 2022; Pfreundschuh, 2022) or confusion of interpreting what is or is not a processed food (Martin, 2022). Caloric content was

standardized in order to eliminate the potentially confounding effect of energy intake, as suggested by Pagliai et al. (2021). As a result, observed effects can be attributed to the difference between the minimally processed foods and their corresponding ultra-processed forms.

Verbal Learning

All four measures of verbal learning that reached statistical significance demonstrated a beneficial impact of minimally processed food, as opposed to ultra-processed food. Minimally processed meals resulted in higher total recall, interference list score, delayed recall, and recognition. In some ways, these results are surprising given the previous lack of significant correlations between processing level of food consumed and verbal memory in general (Gonçalves et al., 2023; Weinstein et al., 2023), immediate memory (Akbaraly et al., 2009, Cardoso et al., 2022), and delayed recall (Cardoso et al., 2022). Cardoso et al. (2022) observed negative trends between ultra-processed food consumption and verbal learning, but with self-reported dietary data and the non-interventional nature of the study's design, their results did not reach statistical significance.

On the other hand, the positive relationship between minimally processed food and verbal learning is to be expected given the broader context of studies on processing level and cognition or academic outcomes. Several authors demonstrated inverse correlations between ultra-processed food and general cognition (Gonçalves et al., 2023; Melo et al., 2022; Ozawa et al., 2017; Torres et al., 2012; Weinstein et al., 2023). Similarly, quasi-experimental studies demonstrated improved academic outcomes with less processed foods (Anderson et al., 2018; Belot & James, 2011; Doku et al., 2013; Hollar et al., 2010; Neumark-Sztainer et al., 1996; Peltzer & Pengpid, 2015). Because the RAVLT correlates with general cognitive ability (Denhart, 2018), a significant causal relationship between processing level and verbal learning is not surprising.

Verbal Fluency

Verbal fluency includes phonemic and semantic fluency, which test participants' ability to list words that start with a given letter or fit a given category, respectively. Perhaps the most surprising finding of this study was the significantly improved phonemic fluency score for those who ate an ultra-processed meal. Akbaraly et al. (2009) found that ultra-processed food consumption correlated negatively with phonemic fluency when controlling for health and demographic factors. Weinstein et al. (2023) also found a negative correlation between ultra-processed food and phonemic fluency, but only when focusing on ultra-processed dairy and participants with a BMI of 30 or greater. Finally, the fact that fast food consumption correlates with lower executive functioning in college students (Pilato et al., 2020) also suggests that verbal fluency, which measures executive function and verbal ability, would decrease with ultra-processed food consumption as well.

Nevertheless, the processing level effect was significant with a large effect size, explaining 39% of the variation in the data. The specific mechanism for this result is unknown. However, due to the documented causal impacts of glucose on cognition (Bellisle, 2004), it is possible that the higher level of free sugar in the ultra-processed meal increased the participants' ability to list words that start with a given letter. It is unknown if this relationship would hold when comparing foods with a lower ratio of carbohydrates to other macronutrients.

Those who ate an ultra-processed meal also demonstrated more frequent switches during the phonemic fluency context. Switching between clusters is an indicator of cognitive flexibility (Strauss et al., 2006). However, these results should be interpreted with caution, as participants were not explicitly directed to switch clusters as frequently as possible; they were simply instructed to list as many words as possible that fit the given prompt. It is possible that the results could have been nonsignificant or reversed if participants were instructed to maximize switches.

Regarding semantic fluency, specifically, the nonsignificant result in the present study is at odds with previous literature that demonstrated an inverse relationship between ultra-processed food and semantic fluency (Akbaraly et al., 2009; Cardoso et al., 2022). As with phonemic fluency, Weinstein et al. (2023) only found significant relationships between ultra-processed dairy consumption and semantic fluency for participants with a BMI of 30 or greater. Therefore, it may be that this relationship requires a larger sample size to detect significant differences, or that these differences only exist for certain sub-categories of participants or foods.

Maslow's Theory of Needs

Finally, this study added to the existent literature that applies Maslow's theory of needs to nutrition and learning (Chinyoka, 2014; Griffin, 2015; Makero & Bii, 2018; Savas et al., 2017; Tshisikhawe, 2017). The present study's results support Maslow's idea that physiological needs are supportive of self-actualization needs. For example, 90 minutes after breakfast, overall participant performance generally declined. Phonemic fluency and proactive interference improved, but performance declined regarding total recall, immediate memory, delayed recall, recognition, retention, and retroactive interference. These results reinforce Martin's (2022) suggestion that hunger, or at least extended postprandial time, interferes with higher-level learning needs.

Similarly, this study supports the idea that nutritional quality represents an aspect of physiological needs that is distinct from mere calories alone (Cassar, 2022; Taormina and Gao, 2013). Both minimally processed and ultra-processed meals were intentionally matched at 400 kilocalories, and other potentially confounding sources of variation were eliminated by experimental design. Therefore, the statistically significant differences in outcomes must have originated from nutritional differences in the meals themselves, as opposed to caloric intake.

Although physiological needs are supportive of self-actualization needs, the present results do not suggest the level of pre-potency and sequentiality that Maslow described. As suggested by Kendrick et al. (2010, p. 293), the needs for high-quality food and learning are interconnected and overlapping; higher-level needs can still be satisfied without full satisfaction of all lower-level needs (Hale et al., 2019; Kendrick et al., 2010; Martin, 2022). For example, even when food quality is sub-optimal, learning can still occur. The results bear this out, as participants learned at least some verbal information regardless of their breakfast processing level. Indeed, a cognitive outcome (e.g., phonemic fluency) may even improve on a low-quality diet. Again, the mechanisms behind this finding are unknown but could be explored in future research.

Implications

This study has several implications for various stakeholders. In the following section, implications are discussed in sequence for individuals, institutions of learning, food production companies, and those who create broader food policies.

Individuals

For individual learners interested in applying this study to their own learning, these results can inform decisions regarding both timing and type of food consumed. Regarding timing, six of the eight measures of verbal learning declined 90 minutes after beginning a meal. These effects included the ability to recall learned verbal information immediately, after a 20-minute delay, after a distractor list, when identifying words from a list of options, and as a running total over five trials. Proactive and retroactive interference had opposing effects. At 90 minutes, it was more difficult for participants to remember previously learned material after a distraction. However, at 30 minutes, it was more difficult to learn new material after having previously learned old material. In general, these results might imply that a learner would benefit

from more frequent food intake, as opposed to having long periods of time (e.g., >90 minutes) in between meals. Of course, this strategy may have additional unintended consequences. For example, this strategy could easily increase overall caloric intake beyond daily recommendations if the dietary change were not planned intentionally.

Individual learners wishing to apply this study to their own learning can also consider the type of food they consume before they engage in learning activities. Four of eight measures of verbal learning showed significant improvement with a minimally processed breakfast. These effects include the ability to recall learned verbal information after a 20-minute delay, on a secondary distractor list, when identifying words from a list of options, and as a running total over five trials. None of the measures of verbal learning had improved results when consuming an ultra-processed meal. These results would imply that a student learning verbal information would benefit from choosing less processed breakfast options.

The individual implications regarding phonemic fluency are more nuanced than those related to verbal learning. Phonemic fluency was significantly greater following an ultra-processed breakfast, and it was also greater at 90 minutes of postprandial time. This may imply that if verbal ability itself is more highly valued for a task than learning (e.g., a presentation vs. a learning activity), an ultra-processed meal may be more beneficial. However, several caveats come with that strategy. First, at 90 minutes, the higher verbal fluency score for ultra-processed meals came with a potential cost in the form of increased errors (intrusions). This difference (p = .03) did not reach statistical significance due to the correction for familywise error rate. However, if accuracy is highly valued in the task under consideration, one might consider if the benefits of higher verbal ability outweigh the potential for mistakes. The second major caveat is that ultra-processed food has a documented causal impact on obesity (Hall et al., 2019) and an association with a host of maladies, including cancer (Elizabeth et al., 2020; Fiolet et al., 2018;

Lane et al., 2021), cardiovascular disease (de Miranda et al., 2021; Elizabeth et al., 2020; Lane et al., 2021; Pagliai et al., 2021; Srour et al., 2019; Yang et al., 2020; Zhang et al., 2021), and type-2 diabetes (Elizabeth et al., 2020; Srour et al., 2019). Ultra-processed food has a dose-dependent relationship with all-cause mortality, such that five servings of ultra-processed food per day increases the risk of all-cause mortality by 62% (Rico-Campà et al., 2019). Therefore, regularly consuming ultra-processed food cannot ethically be recommended (Elizabeth et al., 2020).

Based on the present results and the literature cited in Chapter II, minimally processed diets are recommended overall for physical health, mental health, cognition, and academic performance. Berding et al. (2021) wrote, “While the evidence from intervention studies in humans is limited, the existing data consistently support increasing the intake and variety of plant foods and reducing or eliminating ultra-processed foods" (p. 127). Despite the investment of time and energy required to prepare minimally processed foods for oneself, this strategy appears to be the most effective way to limit the consumption of ultra-processed foods. The dietary guidelines for Americans affirm that “when adults prepare meals themselves, they have more control over the types of food ingredients selected and can focus on choosing nutrient-dense options that contribute to food group goals with little or no added sugars and saturated fat and less sodium” (USDA & HHS, 2020, p. 104). Batch cooking and freezing leftovers may help ameliorate the frequently cited barrier of limited time (Blum et al., 2022; Schnettler et al., 2015). Self-cooked meals will likely have additional benefits, as they are a protective factor for all four quality of life domains in university students: psychological, physical, environment, and social relationship (Lanuza et al., 2022).

Institutions of Learning

For institutions that exist to facilitate learning, it is in the institution’s best interests to design policies, systems, structures, and local food environments that are conducive to learning.

In the words of Cassar (2022), “School food policy is education policy and should be examined as such” (p. 22). The most logical starting point for policy change is the food served in the institution’s own cafeterias. Reforming cafeteria food offerings has been recommended at both the secondary and post-secondary levels (Martin, 2022; Lanuza et al., 2022). If the institution itself is primarily serving food that has documented harmful, causal impacts on verbal learning, obesity (Hall et al., 2019), and cancer (International Agency for Research on Cancer, 2015), one must wonder if the benefits of convenience outweigh the potential for lost learning or future years of life lost or lived with disability (Afshin et al., 2019).

Institutions of learning should also examine how they can address the food insecurity that can lead to the consumption of cheap ultra-processed food. Willis (2021, p. 13) describes college campus food insecurity as a “public health issue.” Setting an optimistic goal for the future, Willis goes on to write

> The university could be a site where disparities in health outcomes and access to basic needs are minimized and equality of opportunity is more fully realized. If it seems absurd to suggest that universities ought to assure access to basic needs for their students, then this may be because we have come to think of higher education as we do any other commodity—a product for purchase, batteries (i.e. energy sources) not included—rather than a public good. Alternatively, if the purpose of the university is to develop students into an informed, thoughtful and skilled populace, then it is absurd not to ensure their access to basic needs (p. 14)

Regardless of the extent to which institutions embrace Willis’ vision, there are many ways to increase access to healthful food while simultaneously “reduc[ing] the access and exposure of the population to ultra-processed food” (Andrade et al., 2021, p. 13). These include increased presence of water fountains, Supplemental Nutrition Assistance Program coordination,

farmer's markets, shuttle services, subsidized food delivery, community gardens, community refrigerators, changing the food supply in dining halls, and nutrition education classes and interventions (Blum et al., 2022; Lanuza et al., 2022; Martin, 2022; Shi et al., 2022). The latter can be particularly effective at reducing ultra-processed food consumption when they include components to enhance self-efficacy in culinary skills in addition to nutritional knowledge (Inácio et al., 2022).

Food Companies

Although it may seem unlikely that for-profit food organizations will voluntarily substitute healthier food preparation methods for those that have already been optimized to reduce costs and maximize sales, this is precisely what several researchers, along with the U.S. government, are asking them to do. The most recent dietary guidelines for Americans state,

> Because sodium is found in foods and beverages across all food groups, with most coming from foods that have salt added during commercial processing rather than salt added to foods during or after preparation, reducing sodium consumption will require a joint effort by individuals, the food and beverage industry, and food service and retail establishments (USDA & HHS 2020, p. 102)

For example, a choice to cut back on added salt in the processed food industry would lessen the number one source of sodium in the American diet (USDA & HHS, 2020).

In addition to the U.S. government, others have suggested these changes as well. In their groundbreaking study documenting the causal relationship between ultra-processed food and obesity, Hall et al. (2019) recommended reformulating ultra-processed foods to ameliorate their health problems while keeping convenience and palatability. The International Agency for Research on Cancer (2021) also suggested motivating manufacturers to improve the healthfulness of their products. These proposed ready-to-eat, yet less processed, formulations are

likely to cost more than their ultra-processed counterparts. However, there may be an emerging market in consumers willing to pay more for healthful food. In a study on the feasibility of a produce prescription program, participants expressed willingness to pay up to $10 per meal for minimally processed meals that also involved minimal kitchen preparation (Wu et al., 2022). To find examples of pre-made, yet minimally-processed, foods, consumers can check the ingredient list to see if it contains salt, oil, sugar or other processed culinary ingredients rarely used in home kitchens (Monteiro, Cannon, Levy, et al., 2019).

Policymakers

As was suggested for institutions of learning, policymakers on a larger scale should also be aware of the impact of ultra-processed food on learning, physical health, and mental health. Countries outside of the U.S., including Brazil, Israel, and Chile, have already enacted policies aimed to limit consumption of ultra-processed food, promote and privilege minimally processed food, and label food more clearly (Beslay et al., 2020; Coletro et al., 2022; Juul et al., 2022; Srour et al., 2019). The Brazilian dietary guidelines clearly recommend a higher proportion of minimally processed food (Coletro et al., 2022), and the French national food guidelines have a goal of lowering the percent of calories consumed from ultra-processed food by 20% in five years (Andrade et al., 2021).

The United States has no such policies related to ultra-processed food, and this term is not directly addressed in the dietary guidelines for Americans (Juul et al., 2022). A clear statement is recommended regarding ultra-processed food in the dietary guidelines for Americans (Capra, 2022) as well as additional public health recommendations discouraging the consumption of ultra-processed food (Martinez-Perez et al., 2021; Pagliai et al., 2021). Similar recommendations have been made for policy changes to the National School Lunch Program (Cassar, 2022).

Beyond words alone, practical strategies can be enacted to promote minimally processed food while simultaneously discouraging the consumption of ultra-processed foods. Similar to strategies that have been used with other harmful substances in the past, these strategies can shift the patterns of consumption toward less processed foods (Weinstein, et al., 2022). One solution with a net neutral financial impact is the taxation of ultra-processed food while using the revenue to subsidize minimally processed food (Coyle et al., 2022; Pfreundschuh, 2022). The overall result of making minimally processed food more available and affordable is particularly important for those with low socioeconomic status (Juul et al., 2022). Policies can also be designed to limit advertising and availability of ultra-processed food in schools and hospitals (Coyle et al., 2022; Lemos, 2022).

Improved labeling of ultra-processed foods is also widely recommended at the national level (Fondevila-Gascón et al., 2022; Juul et al., 2022; Lemos, 2022). The World Health Organization developed the Nutri-Score label as a data-driven way to help consumers make healthy choices. It is designed as a front-of-pack, easy-to-understand label with a color-coded letter grade (A, B, C, etc..) that indicates relative risk for developing chronic disease. The system awards points based on the amount of energy, saturated fatty acids, sugars, sodium, dietary fibers, proteins, fruits, vegetables, legumes, nuts, olive, canola oil, and nut oils per 100g or 100mL beverage. It has been adopted by seven countries in Europe, but not yet in the United States (IARC, 2021).

Limitations

Despite its strong experimental design, this study had several limitations. The primary limitation was the necessity to choose specific conditions for the experiment. For example, it is unknown whether or not alternate choices for minimally processed vs. ultra-processed breakfasts would have resulted in the same outcomes. This limitation was necessary in order to gain the

validity of a strong experimental design capable of demonstrating causation. The foods in the study were chosen to maximize relevance to commonly consumed breakfast items while also providing a direct comparison between minimally processed and ultra-processed forms of a given food. It is impossible to test all possible breakfast foods in one experimental study, so this limitation was unavoidable. Similarly, the necessity of choosing the amount of food provided and the timing of tests was also an unavoidable limitation. The latter may be particularly influential, as the postprandial period involves fluctuations in parameters such as blood sugar levels; these parameters may manifest differently depending on a food's processing level (O'Keefe et al., 2008).

Other limitations were related to the sample itself. Although random selection of participants was desired, a voluntary response sample was ultimately chosen. Random selection of participants would have improved generalization to the entire population of interest (Suter, 2012, p. 236). However, due to practical constraints, experiments in education are "rarely, if ever, based on random samples" (Johnson & Christensen, 2019, p. 255).

Regarding sample size, forty-eight participants originally responded to the initial request for participation, but eight failed to respond to subsequent communication and never began the study. This dropout rate still left a large sample size of forty participants, and all participants who were randomized to start the study finished the study. However, it is possible that additional results could have reached statistical significance with an even larger sample size. The sample size was large enough to satisfy the normality assumption of the parametric analysis, but the lack of evidence for normality in some data sets represented an additional limitation.

Finally, the controlled, lab-like nature of the study itself is a limitation. This level of control was necessary to demonstrate causation, but it sacrificed some relevance to traditional educational settings. For example, social interaction is often a part of educational experiences;

however, in order to control for confounding influences and prevent diffusion, each participant listened to prompts through headphones and typed responses individually on their own computers. Even though solitary learning experiences may become more common in an age of online schooling, the limitation still holds for relevance to traditional learning settings.

Recommendations for Future Research

Based on the present study, several recommendations can be made for future research. First, as discussed previously in the limitations section, this study should be replicated with additional examples of minimally processed vs. ultra-processed food and timeframes. It may be particularly instructive to include foods with a lower ratio of carbohydrates to other macronutrients and longer end-points for post-prandial time. Because the processing level effect on phonemic fluency was unexpected, it would be useful to see if this effect persists in other variations of the experiment.

Second, because the RAVLT correlates with general cognitive ability (Denhart, 2018), the four significant relationships between processing level and verbal learning indicate the importance of future research on other areas of cognition as well. Based on the high number of statistically significant results with verbal learning and verbal fluency, future tests should expand to include additional neuropsychological tests as well (Pilato et al., 2020).

Third, due to the inconsistency between the present results and correlational results on processing level and semantic fluency, future studies should re-test this connection with a strong experimental design. It is possible that with a larger sample size or different forms of the test, a significant result may appear. Cardoso et al. (2022) suggested longitudinal studies on ultra-processed food and semantic fluency, which may add ecological validity to any short-term repeated-measures studies.

Finally, this type of study should be repeated in a secondary setting, with the proper parental permissions and informed consent. Information on youth and young adults is limited in this context of diet and cognition (Martin, 2022; Gauci, 2022). Secondary learners represent a large proportion of those engaged in formal schooling, and they consume 68% of their calories in the form of ultra-processed food (Martínez Steele et al., 2020). Therefore, it would be beneficial to see if their learning would also benefit from the consumption of minimally processed food.

Conclusions

The purpose of this study was to determine the unknown causal impact of processing level of food consumed and postprandial time on verbal learning and fluency. Through a randomized, controlled trial with a repeated-measures design, 16 statistically significant effects were discovered. Verbal learning measures were generally stronger at 30 minutes, whereas phonemic fluency measures were generally stronger at 90 minutes. There were no significant relationships involving semantic fluency. Phonemic fluency was improved in the ultra-processed group. However, in the context of verbal learning, total recall, interference list score, delayed recall, and recognition were significantly improved with the minimally processed meal. It is noteworthy that all of these effects were discernable after a single meal change.

This study informed several gaps in the literature. First, it directly tested the causal connection between processing level of food consumed and several measures of cognition through a strong experimental design. At the same time, the nutritional lens of the study was the growing field of food synergy as opposed to nutrient reductionism (Fardet & Rock, 2018). Furthermore, the study focused on an under-studied age demographic of young adults (Pilato et al., 2020). Finally, this study contributed to the literature on Maslow's theory of needs. The basic idea of Maslow's theory was supported by the significant relationships between the self-actualization need of learning and both postprandial time and nutritional quality. However, the

data also supported the proposed revision to Maslow's theory that higher-level needs can still be satisfied to some extent without full satisfaction of all lower-level needs (Hale et al., 2019; Kendrick et al., 2010; Martin, 2022). Future studies could further confirm and expand on these results with an even younger demographic and additional food comparisons.

To enhance learning while also limiting potential chronic disease, it is recommended that institutions of learning and policymakers create environments that favor minimally processed food consumption over ultra-processed food consumption. Institutions of learning can evaluate the type of food served in their own cafeterias and consider creative ways to get nutrient-dense foods on the plates of their learners (Blum et al., 2022; Lanuza et al., 2022; Martin, 2022; Shi et al., 2022). Both independent researchers and the U.S. government have called upon food companies to modify their formulations to improve their nutrition quality (Hall et al., 2019; International Agency for Research on Cancer; USDA & HHS, 2020). Finally, state and federal policymakers can make clear statements regarding processing level of food consumed, incentivize minimally processed foods, and institute informative and intuitive front-of-box nutrition labeling (Capra, 2022; Fondevila-Gascón et al., 2022; Weinstein, et al., 2022). Considering the simultaneous challenges of food insecurity, food deserts, and global epidemics of obesity, cardiovascular disease, and type 2 diabetes (Blum et al., 2022; Pontoppidan et al., 2024; Pfreundschuh, 2022), some would argue that the ethic of care (Shapiro & Stefkovitch, 2016) obligates policymakers to make these changes a reality.

Regardless of whether or not the aforementioned recommendations are enacted by governments, food companies, universities, and schools, individuals can still make choices to control their own dietary patterns. Prioritizing self-preparation of meals is a powerful step in taking control of one's diet (USDA & HHS, 2020). Minimally processed convenience foods, though less common than their ultra-processed counterparts, can also fill the need for ready-to-

eat food; these can be identified by ingredient lists without salt, oil, sugar, or ingredients rarely used in home kitchens (Monteiro, Cannon, Levy, et al., 2019).

Chapter I began with the observation that poor nutrition is the single most important factor contributing to years of life lost or lived with disability (Afshin et al., 2019). The inverse also appears to be true; Campbell (2005) wrote, "Good nutrition creates health in all areas of our existence. All parts are interconnected" (p. 238). There may be additional causal connections between food processing level and academic outcomes that are currently unknown. It is my hope that this study is the first of many to put these connections to the test.

References

Adams, A. T., Ulrich, M. J., & Coleman, A. (2010). Food deserts. *Journal of Applied Social Science*, *4*(2), 58–62. https://doi.org/10.1177%2F193672441000400206

Adams, M., Blumenfeld, W., Castaneda, R., Hackman, H., & Peters, M., Zuniga, X. (2013). *Readings for diversity and social justice* (3rd ed.). Routledge.

Adjibade, M., Julia, C., Allès, B., Touvier, M., Lemogne, C., Srour, B., Hercberg, S., Galan, P., Assmann, K. E. & Kesse-Guyot, E. (2019). Prospective association between ultra-processed food consumption and incident depressive symptoms in the French NutriNet-Santé cohort. *BioMed Central Medicine*, *17*(1), 1–13. https://doi.org/10.1186/s12916-019-1312-y

Afshin, A., Sur, P. J., Fay, K. A., Cornaby, L., Ferrara, G., Salama, J. S., Mullany, E. C., Abate, K. H., Abbafati, C., Abebe, Z., Afarideh, M., Aggarwal, A., Agrawal, S., Akinyemiju, T., Alahdab, F., Bacha, U., Bachman, V., Badali, H., Badawi, A., ... & Murray, C. J. (2019). Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *The Lancet*, *393*(10184), 1958–1972. https://doi.org/10.1016/S0140-6736(19)30041-8

Aguilera, J. M. (2019). The food matrix: Implications in processing, nutrition, and health. *Critical Reviews in Food Science and Nutrition*, *59*(22), 3612–3629. https://doi.org/10.1080/10408398.2018.1502743

Akbaraly, T. N., Singh-Manoux, A., Dugravot, A., Brunner, E. J., Kivimäki, M., & Sabia, S. (2019). Association of midlife diet with subsequent risk for dementia. *JAMA*, *321*(10), 957–968. https://doi.org/10.1001/jama.2019.1432

Akbaraly, T. N., Singh-Manoux, A., Marmot, M. G., & Brunner, E. J. (2009). Education attenuates the association between dietary patterns and cognition. *Dementia and Geriatric Cognitive Disorders*, *27*(2), 147–154. https://doi.org/10.1159/000199235

Al-Musharaf, S., AlAjllan, L., Aljuraiban, G., AlSuhaibani, M., Alafif, N., & Hussain, S. D. (2022). Nutritional biomarkers and factors correlated with poor sleep status among young females: A case-control study. *Nutrients*, *14*(14), 2898. https://doi.org/10.3390/nu14142898

Alloway, T. P., Gathercole, S. E., Kirkwood, H., & Elliott, J. (2009). The cognitive and behavioral characteristics of children with low working memory. *Child Development*, *80*(2), 606–621. https://doi.org/10.1111/j.1467-8624.2009.01282.x

Anderson, A., Lazarus, J., & Anderson Steeves, E. (2022). Navigating hidden hunger: An exploratory analysis of the lived experience of food insecurity among college students. *International Journal of Environmental Research and Public Health*, *19*(19), 12952. https://doi.org/10.3390/ijerph191912952

Anderson, M. L., Gallagher, J., & Ritchie, E. R. (2018). School meal quality and academic performance. *Journal of Public Economics*, *168*, 81–93. https://doi.org/10.1016/j.jpubeco.2018.09.013

Andrade, G. C., Julia, C., Deschamps, V., Srour, B., Hercberg, S., Kesse-Guyot, E., Allès, B., Chazelas, E., Deschasaux, M., Touvier, M., Augusto Monteiro, C., & Bertazzi Levy, R. (2021). Consumption of ultra-processed food and its association with sociodemographic characteristics and diet quality in a representative sample of French adults. *Nutrients*, *13*(2), 682. https://doi.org/10.3390/nu13020682

Askari, M., Heshmati, J., Shahinfar, H., Tripathi, N., & Daneshzad, E. (2020). Ultra-processed food and the risk of overweight and obesity: A systematic review and meta-analysis of

observational studies. *International Journal of Obesity*, *44*(10), 2080–2091. https://doi.org/10.1038/s41366-020-00650-z

Attuquayefio, T., & Stevenson, R. J. (2015). A systematic review of longer-term dietary interventions on human cognitive function: Emerging patterns and future directions. *Appetite*, *95*, 554–570. https://doi.org/10.1016/j.appet.2015.08.023

Attuquayefio, T., Stevenson, R. J., Oaten, M. J., & Francis, H. M. (2017). A four-day Western-style dietary intervention causes reductions in hippocampal-dependent learning and memory and interoceptive sensitivity. *PLoS One*, *12*(2), e0172645. https://doi.org/10.1371/journal.pone.0172645

Baker, P., Machado, P., Santos, T., Sievert, K., Backholer, K., Hadjikakou, M., Russell, C., Huse, O., Bell, C., Scrinis, G., Worsley, A., Friel, S., & Lawrence, M. (2020). Ultra-processed foods and the nutrition transition: Global, regional and national trends, food systems transformations and political economy drivers. *Obesity Reviews*, *21*(12), e13126. https://doi.org/10.1111/obr.13126

Balogh, R., Imre, N., Gosztolya, G., Pákáski, M., & Kálmán, J. (2023). The role of silence in verbal fluency tasks–a new approach for the detection of mild cognitive impairment. *Journal of the International Neuropsychological Society*, *29*(1), 46–58. https://doi.org/10.1017/S1355617721001454

Baraldi, L. G., Steele, E. M., Canella, D. S., & Monteiro, C. A. (2018). Consumption of ultra-processed foods and associated sociodemographic factors in the USA between 2007 and 2012: Evidence from a nationally representative cross-sectional study. *British Medical Journal Open*, *8*(3), e020574. https://doi.org/10.1136/bmjopen-2017-020574

Barnard, N. D., Bunner, A. E., & Agarwal, U. (2014). Saturated and trans fats and dementia: A systematic review. *Neurobiology of Aging*, *35*, S65–S73. https://doi.org/10.1016/j.neurobiolaging.2014.02.030

Beilharz, J. E., Maniam, J., & Morris, M. J. (2015). Diet-induced cognitive deficits: The role of fat and sugar, potential mechanisms and nutritional interventions. *Nutrients*, *7*(8), 6719–6738. https://doi.org/10.3390/nu7085307

Bellisle, F. (2004). Effects of diet on behaviour and cognition in children. *British Journal of Nutrition*, *92*(S2), S227–S232. https://doi.org/10.1079/BJN20041171

Belot, M., & James, J. (2011). Healthy school meals and educational outcomes. *Journal of Health Economics*, *30*(3), 489–504. https://doi.org/10.1016/j.jhealeco.2011.02.003

Benton, A. L. (1968). Differential behavioral effects in frontal lobe disease. *Neuropsychologia*, *6*(1), 53–60. https://doi.org/10.1016/0028-3932(68)90038-9

Benton, A. L., Hamsher, K. deS., & Sivan, A. B. (1994). *Multilingual aphasia examination* (3rd ed.). Psychological Corporation.

Berding, K., Vlckova, K., Marx, W., Schellekens, H., Stanton, C., Clarke, G., Jacka, F., Dinan, T.G., & Cryan, J. F. (2021). Diet and the microbiota–gut–brain axis: Sowing the seeds of good mental health. *Advances in Nutrition*, *12*(4), 1239–1285. https://doi.org/10.1093/advances/nmaa181

Berendsen, A. M., Kang, J. H., Feskens, E. J., de Groot, C. P. G. M., Grodstein, F., & van de Rest, O. (2018). Association of long-term adherence to the mind diet with cognitive function and cognitive decline in American women. *The Journal of Nutrition, Health & Aging*, *22*(2), 222–229. https://doi.org/10.1007/s12603-017-0909-0

Bernice, P. J. (2021). *Impact of healthy eating patterns on cognitive function: A systematic review and meta-analysis of randomised controlled trials* [Doctoral dissertation, National

University of Singapore]. ScholarBank. https://scholarbank.nus.edu.sg/handle/10635/188052

Beslay, M., Srour, B., Méjean, C., Allès, B., Fiolet, T., Debras, C., Chazelas, E., Deschasaux, M., Wendeu-Foyet, M. G., Hercberg, S. Galan, P., Monteiro , C. A. Deschampts, V. Andrade, G. C., Kesse-Guyot, E., Julia, C., & Touvier, M. (2020). Ultra-processed food intake in association with BMI change and risk of overweight and obesity: A prospective analysis of the French NutriNet-Santé cohort. *PLoS Medicine, 17*(8), e1003256. https://doi.org/10.1371/journal.pmed.1003256

Bird, C. M., Papadopoulou, K., Ricciardelli, P., Rossor, M. N., & Cipolotti, L. (2004). Monitoring cognitive changes: Psychometric properties of six cognitive tests. *British Journal of Clinical Psychology*, *43*(2), 197–210. https://doi.org/10.1348/014466504323088051

Blum, M., Hu, C., Lin, C., Stefanowicz, A., Sun, H. T., & Zhou, C. (2022). Challenges and Solutions to Increase Fresh Food Consumption in Food Desert and College Campus. In K. Ellis, W. Ferrell & J. Knapp (Eds.) *Institute of Industrial & System Engineers Annual Conference*, 1–6. https://bpb-us-w2.wpmucdn.com/sites.gatech.edu/dist/4/1481/files/2022/05/Final-IISE-Annual-Conference-Paper.pdf

Boespflug, E. L., Eliassen, J. C., Dudley, J. A., Shidler, M. D., Kalt, W., Summer, S. S., Stein, A. L., Stover, A. N. & Krikorian, R. (2018). Enhanced neural activation with blueberry supplementation in mild cognitive impairment. *Nutritional Neuroscience*, *21*(4), 297–305. https://doi.org/10.1080/1028415X.2017.1287833

Bonyadi, N., Dolatkhah, N., Salekzamani, Y., & Hashemian, M. (2022). Effect of berry-based supplements and foods on cognitive function: A systematic review. *Scientific Reports*, *12*(1), 1–14. https://doi.org/10.1038/s41598-022-07302-4

Bowen, K. J., Sullivan, V. K., Kris-Etherton, P. M., & Petersen, K. S. (2018). Nutrition and cardiovascular disease—an update. *Current Atherosclerosis Reports*, *20*(8), 1–11. https://doi.org/10.1007/s11883-018-0704-3

Bradley, B. J., & Greene, A. C. (2013). Do health and education agencies in the United States share responsibility for academic achievement and health? A review of 25 years of evidence about the relationship of adolescents' academic achievement and health behaviors. *Journal of Adolescent Health*, *52*(5), 523–532. https://doi.org/10.1016/j.jadohealth.2013.01.008

Bruening, M., Argo, K., Payne-Sturges, D., & Laska, M. N. (2017). The struggle is real: A systematic review of food insecurity on postsecondary education campuses. *Journal of the Academy of Nutrition and Dietetics*, *117*(11), 1767–1791. https://doi.org/10.1016/j.jand.2017.05.022

Buckley, J. P., Kim, H., Wong, E., & Rebholz, C. M. (2019). Ultra-processed food consumption and exposure to phthalates and bisphenols in the US National Health and Nutrition Examination Survey, 2013–2014. *Environment International*, *131*, 105057. https://doi.org/10.1016/j.envint.2019.105057

Caldwell, K., Charlton, K. E., Roodenrys, S., & Jenner, A. (2016). Anthocyanin-rich cherry juice does not improve acute cognitive performance on RAVLT. *Nutritional Neuroscience*, *19*(9), 423–424. https://doi.org/10.1179/1476830515Y.0000000005

Campbell II, T. M. (2005). *The China study: the most comprehensive study of nutrition ever conducted and the startling implications for diet, weight loss and long-term health*. BenBella Books, Inc.

Capra, B., Matthews, E., Kerrihard, A., & Hosick, P. (2022). Associations between ultra-processed food consumption and BMI, sedentary time, and adverse dietary habits in active young adults. *Journal of Exercise and Nutrition*, *5*(1), 7. https://doi.org/10.53520/jen2022.103121

Cardoso, B. R., Machado, P., & Steele, E. M. (2022). Association between ultra-processed food consumption and cognitive performance in US older adults: a cross-sectional analysis of the NHANES 2011–2014. *European Journal of Nutrition*, *61*(8), 3975–3985. https://doi.org/10.1007/s00394-022-02911-1

Casaletto, K. B., & Heaton, R. K. (2017). Neuropsychological assessment: Past and future. *Journal of the International Neuropsychological Society*, *23*(9), 778–790. https://doi.org/10.1017/S1355617717001060

Cassar, E. M. (2022). Hunger and fullness: How high-poverty urban students experience school food policy. *Urban Education*, *57*(8), 1387–1414. https://doi.org/10.1177/0042085918805147

Cervera Burriel, F., Serrano Urrea, R., Vico García, C., Milla Tobarra, M., & García Meseguer, M. J. (2013). Hábitos alimentarios y evaluación nutricional en una población universitaria. *Nutrición Hospitalaria*, *28*(2), 438–446. https://dx.doi.org/10.3305/nh.2013.28.2.6303

Chinyoka, K. (2014). Impact of poor nutrition on the academic performance of grade seven learners: a case of Zimbabwe. *International Journal of Learning & Development*, *4*(3). 73–84 http://dx.doi.org/10.5296/ijld.v4i3.6169

Cohen, C. (2020). *Reliability and validity of alternate category fluency forms in mild cognitive impairment and cognitively intact individuals* [Doctoral dissertation, Rosalind Franklin University of Medicine and Science]. ProQuest Dissertations & Theses Global. https://www.proquest.com/openview/816232bc4df75bc77a9833e2f42f0059/1?pq-origsite=gscholar&cbl=44156

Coletro, H. N., de Deus Mendonça, R., Meireles, A. L., Machado-Coelho, G. L. L., & de Menezes, M. C. (2022). Ultra-processed and fresh food consumption and symptoms of anxiety and depression during the COVID–19 pandemic: COVID Inconfidentes. *Clinical nutrition ESPEN*, *47*, 206–214. https://doi.org/10.1016/j.clnesp.2021.12.013

Costa, C. D. S., Assunção, M. C. F., Loret de Mola, C., Cardoso, J. D. S., Matijasevich, A., Barros, A. J., & Santos, I. S. (2021). Role of ultra-processed food in fat mass index between 6 and 11 years of age: A cohort study. *International Journal of Epidemiology*, *50*(1), 256–265. https://doi.org/10.1093/ije/dyaa141

Costa, C. S., Del-Ponte, B., Assunção, M. C. F., & Santos, I. S. (2018). Consumption of ultra-processed foods and body fat during childhood and adolescence: a systematic review. *Public Health Nutrition*, *21*(1), 148–159. https://doi.org/10.1017/S1368980017001331

Coyle, D. H., Huang, L., Shahid, M., Gaines, A., Di Tanna, G. L., Louie, J. C. Y., Pan, X., Marklund, M., Neal, B., & Wu, J. H. (2022). Socio-economic difference in purchases of ultra-processed foods in Australia: An analysis of a nationally representative household grocery purchasing panel. *International Journal of Behavioral Nutrition and Physical Activity*, *19*(1), 1–10. https://doi.org/10.1186/s12966-022-01389-8

Crandall, A., Powell, E. A., Bradford, G. C., Magnusson, B. M., Hanson, C. L., Barnes, M. D., Novilla, M. L. B. & Bean, R. A. (2020). Maslow's hierarchy of needs as a framework for

understanding adolescent depressive symptoms over time. *Journal of Child and Family Studies*, *29*(2), 273–281. https://doi.org/10.1007/s10826-019-01577-4

Creswell, J. W. & Poth, C. N. (2018). *Qualitative inquiry & research design: Choosing among five approaches* (4th ed). Sage.

Cummings, J. R., Schiestl, E. T., Tomiyama, A. J., Mamtora, T., & Gearhardt, A. N. (2022). Highly processed food intake and immediate and future emotions in everyday life. *Appetite*, *169*, 105868. https://doi.org/10.1016/j.appet.2021.105868

Cunje, A., Molloy, D. W., Standish, T. I., & Lewis, D. L. (2007). Alternate forms of logical memory and verbal fluency tasks for repeated testing in early cognitive changes. *International Psychogeriatrics*, *19*(1), 65–75. https://doi.org/10.1017/S1041610206003425

da Costa Penha, S., Norde, M. M., & Carioca, A. A. F. (2022). Childhood eating practices are relevant to ultra-processed food consumption in adulthood: Results from the Nutritionists' Health Study. *Journal of Developmental Origins of Health and Disease*, *13*(5), 583–592. https://doi.org/10.1017/S2040174421000696

Darmon, N., & Drewnowski, A. (2015). Contribution of food prices and diet cost to socioeconomic disparities in diet quality and health: A systematic review and analysis. *Nutrition Reviews*, *73*(10), 643–660. https://doi.org/10.1093/nutrit/nuv027

de Miranda, R. C., Rauber, F., & Levy, R. B. (2021). Impact of ultra-processed food consumption on metabolic health. *Current Opinion in Lipidology*, *32*(1), 24–37. https://doi.org/10.1097/MOL.0000000000000728

de Sousa Magalhães, S., Fernandes Malloy-Diniz, L., & Cavalheiro Hamdan, A. (2012). Validity convergent and reliability test-retest of the Rey Auditory-Verbal learning test. *Clinical Neuropsychiatry*, *9*(3). 129–137. https://psycnet.apa.org/record/2013-15311-003

DeJarnett, N., Conklin, D. J., Riggs, D. W., Myers, J. A., O'Toole, T. E., Hamzeh, I., Wagner, S., Chugh, A., Ramos, K. S., Srivastava, S., Higdon, D., Tollerud, D. J., DeFilippis, A., Becher, C., Wyatt, B., McCracken, J., Abplanalp, W., Shesh, N. R. Ciszewski., X., ... & Bhatnagar, A. (2014). Acrolein exposure is associated with increased cardiovascular disease risk. *Journal of the American Heart Association*, *3*(4), e000934. https://doi.org/10.1161/jaha.114.000934

Delaney, R. C., Prevey, M. L., Cramer, J., Mattson, R. H. (1992). Test-retest comparability and control subject data for the Rey-Auditory-Verbal learning test and Rey-Osterrieth/Taylor complex figures. *Archives of Clinical Neuropsychology*, *7*(6), 523–528. https://doi.org/10.1016/0887-6177(92)90142-A

Delis, D. C., Kaplan, E., & Kramer, J. H. (2001). *Delis-Kaplan executive function system*. Psychological Corporation. https://doi.org/10.1037/t15082-000

Denhart, S. (2018). *A Comparison of the Rey Auditory-Verbal Learning Test and the Wechsler Scales* [Doctoral dissertation, Murray State University]. Education Commons. https://digitalcommons.murraystate.edu/etd/73

Devore, E. E., Kang, J. H., Breteler, M. M., & Grodstein, F. (2012). Dietary intakes of berries and flavonoids in relation to cognitive decline. *Annals of Neurology*, *72*(1), 135–143. https://doi.org/10.1002/ana.23594

Dikmen, S. S., Heaton, R. K., Grant, I., & Temkin, N. R. (1999). Test–retest reliability and practice effects of expanded Halstead–Reitan Neuropsychological Test Battery. *Journal of the International Neuropsychological Society*, *5*(4), 346–356. https://doi.org/10.1017/S1355617799544056

Doku, D., Koivusilta, L., Raisamo, S., & Rimpelä, A. (2013). Socio-economic differences in adolescents' breakfast eating, fruit and vegetable consumption and physical activity in

Ghana. *Public Health Nutrition*, *16*(5), 864–872. https://doi.org/10.1017/S136898001100276X

Drake, I., Sonestedt, E., Ericson, U., Wallström, P., & Orho-Melander, M. (2018). A Western dietary pattern is prospectively associated with cardio-metabolic traits and incidence of the metabolic syndrome. *British Journal of Nutrition*, *119*(10), 1168–1176. https://doi.org/10.1017/S000711451800079X

Dumontheil, I., & Klingberg, T. (2012). Brain activity during a visuospatial working memory task predicts arithmetical performance 2 years later. *Cerebral Cortex*, *22*(5), 1078–1085. https://doi.org/10.1093/cercor/bhr175

Duran, S., Crovetto, M., Espinoza, V., Mena, F., Onate, G., Fernandez, M., Conuecar, S., Guerra, A., & Valladares, M. (2021). Lifestyles, body mass index and sleep patterns among university students. *Chilean Medical Journal*, *145*, 1403–1411. http://repositoriodigital.uct.cl/handle/10925/3984

Dykstra, H., Davey, A., Fisher, J. O., Polonsky, H., Sherman, S., Abel, M. L., Dale, L. C., Foster, G. D., & Bauer, K. W. (2016). Breakfast-skipping and selecting low-nutritional-quality foods for breakfast are common among low-income urban children, regardless of food security status. *The Journal of Nutrition*, *146*(3), 630–636. https://doi.org/10.3945/jn.115.225516

Elizabeth, L., Machado, P., Zinöcker, M., Baker, P., & Lawrence, M. (2020). Ultra-processed foods and health outcomes: A narrative review. *Nutrients*, *12*(7), 1955. https://doi.org/10.3390/nu12071955

Fanning, K. J., Topp, B., Russell, D., Stanley, R., & Netzel, M. (2014). Japanese plums (Prunus salicina Lindl.) and phytochemicals–breeding, horticultural practice, postharvest storage,

processing and bioactivity. *Journal of the Science of Food and Agriculture*, *94*(11), 2137–2147. https://doi.org/10.1002/jsfa.6591

Fanselow, M. S., & Dong, H. W. (2010). Are the dorsal and ventral hippocampus functionally distinct structures?. *Neuron*, *65*(1), 7–19. https://doi.org/10.1016/j.neuron.2009.11.031

Fard, E. K., Keelor, J. L., Bagheban, A. A., & Keith, R. W. (2016). Comparison of the Rey Auditory Verbal Learning Test (RAVLT) and digit test among typically achieving and gifted students. *Iranian Journal of Child Neurology*, *10*(2), 26. https://doi.org/10.22037/ijcn.v10i2.7974

Fardet, A., & Rock, E. (2018). Perspective: Reductionist nutrition research has meaning only within the framework of holistic and ethical thinking. *Advances in nutrition*, *9*(6), 655–670. https://doi.org/10.1093/advances/nmy044

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*, 175–191. https://doi.org/10.3758/bf03193146

Filippello, P., Buzzai, C., Costa, S., & Sorrenti, L. (2019). School refusal and absenteeism: Perception of teacher behaviors, psychological basic needs, and academic achievement. *Frontiers in Psychology*, *10*, 1471. https://doi.org/10.3389/fpsyg.2019.01471

Fiolet, T., Srour, B., Sellem, L., Kesse-Guyot, E., Allès, B., Méjean, C., Deschasaux, M., Fassier, P., Latino-Martel, P., Beslay, M., Hercberg, S., Lavalette, C., Monteiro., C., Julia, C., & Touvier, M. (2018). Consumption of ultra-processed foods and cancer risk: Results from NutriNet-Santé prospective cohort. *British Medical Journal*, *360*, K322. https://doi.org/10.1136/bmj.k322

Florence, M. D., Asbridge, M., & Veugelers, P. J. (2008). Diet quality and academic performance. *Journal of School Health*, *78*(4), 209–215. https://doi.org/10.1111/j.1746-1561.2008.00288.x

Fondevila-Gascón, J. F., Berbel-Giménez, G., Vidal-Portés, E., & Hurtado-Galarza, K. (2022). Ultra-processed foods in university students: Implementing nutri-score to make healthy choices. *Healthcare*, *10*(6), 984. https://doi.org/10.3390/healthcare10060984

Foster, J. A., & Neufeld, K. A. M. (2013). Gut–brain axis: how the microbiome influences anxiety and depression. *Trends in Neurosciences*, *36*(5), 305–312. https://doi.org/10.1016/j.tins.2013.01.005

Fotuhi, M., Do, D., & Jack, C. (2012). Modifiable factors that alter the size of the hippocampus with ageing. *Nature Reviews Neurology*, *8*(4), 189–202. https://doi.org/10.1038/nrneurol.2012.27

Francis, H., & Stevenson, R. (2013). The longer-term impacts of Western diet on human cognition and the brain. *Appetite*, *63*, 119–128. https://doi.org/10.1016/j.appet.2012.12.018

Frisvold, D. E. (2015). Nutrition and cognitive achievement: An evaluation of the School Breakfast Program. *Journal of Public Economics*, *124*, 91–104. https://doi.org/10.1016/j.jpubeco.2014.12.003

Frndak, S. E. (2014). An ecological study of food desert prevalence and 4th grade academic achievement in New York State school districts. *Journal of Public Health Research*, *3*(319), 130–137. https://doi.org/10.4081/jphr.2014.319

Galioto, R., & Spitznagel, M. B. (2016). The effects of breakfast and breakfast composition on cognition in adults. *Advances in Nutrition*, *7*(3), 576S–589S. https://doi.org/10.3945/an.115.010231

Gardener, S. L., Rainey-Smith, S. R., Barnes, M. B., Sohrabi, H. R., Weinborn, M., Lim, Y. Y., Harrington, K., Taddei, K., Gu, Y., Rembach, A. Szoeke, C., Ellis, K. A., Masters, C. L., Rowe, C. C., Ames, D., Keogh, J. B., Scarmeas, N., & Martins, R. N. (2015). Dietary patterns and cognitive decline in an Australian study of ageing. *Molecular Psychiatry*, *20*(7), 860–866. http://dx.doi.org/10.1038/mp.2014.79

Gauci, S. (2022). *Food for thought: The relationship between dietary patterns, cardio-metabolic risk and cognitive performance in middle age and older adults* [Master's thesis, Swinburne University]. Research Bank. https://researchbank.swinburne.edu.au/file/baa52f77-0303-421b-87e4-efa4fb078b6c/1/sarah_gauci_thesis.pdf

Gibney, M. J. (2019). Ultra-processed foods: definitions and policy issues. *Current Developments in Nutrition*, *3*(2), nzy077. https://doi.org/10.1093/cdn/nzy077

Gibney, M. J., Forde, C. G., Mullally, D., & Gibney, E. R. (2017). Ultra-processed foods in human health: A critical appraisal. *The American Journal of Clinical Nutrition*, *106*(3), 717–724. https://doi.org/10.3945/ajcn.117.160440

Goldrick-Rab, S., Broton, K. and Eisenberg, D. (2015) *Hungry to learn: addressing food & housing insecurity among undergraduates*. Wisconsin Hope Lab. https://www.acct.org/files/Publications/2015/Wisconsin_hope_lab_hungry_to_learn.pdf

Gonçalves, N. G., Ferreira, N. V., Khandpur, N., Steele, E. M., Levy, R. B., Lotufo, P. A., Bensenor, I. M., Caramelli, P., de Matos, S. M. A., Marchioni, D. M. & Suemoto, C. K. (2023). Association Between Consumption of Ultraprocessed Foods and Cognitive Decline. *JAMA Neurology*, *80*(2), 142–150. https://doi.org/10.1001/jamaneurol.2022.4397

Gottlieb, A., Doniger, G. M., Kimel-Naor, S., Ben-Gal, O., Cohen, M., Iny, H., Beeri, M. S. & Plotnik, M. (2022). Development and validation of virtual reality-based Rey Auditory Verbal Learning Test. *Frontiers in Aging Neuroscience*, *14*, 1–10. https://doi.org/10.3389/fnagi.2022.980093

Green, S. B. & Salkind, N. J. (2017). *Using SPSS for Windows and Macintosh: Analyzing and understanding data*. (8th ed.). Pearson.

Griffin, L. A. (2015). *The correlation between nutrition and academic achievement in Georgia Middle Schools* [Doctoral dissertation, Liberty University]. Education Commons. https://digitalcommons.liberty.edu/doctoral/4136/

Hale, A. J., Ricotta, D. N., Freed, J., Smith, C. C., & Huang, G. C. (2019). Adapting Maslow's hierarchy of needs as a framework for resident wellness. *Teaching and Learning in Medicine*, *31*(1), 109–118. https://doi.org/10.1080/10401334.2018.1456928

Hall, K. D., Ayuketah, A., Brychta, R., Cai, H., Cassimatis, T., Chen, K. Y., Chung, S. T., Costa, E., Courville, A., Darcey, V. Fletcher, L.A., Forde, C. G., Gharib, A. M., Guo, J., Howard, R., Joseph, P. V., McGehee, S., Ouwerkerk, R., Raisinger, K., & Zhou, M. (2019). Ultra-processed diets cause excess calorie intake and weight gain: an inpatient randomized controlled trial of ad libitum food intake. *Cell Metabolism*, *30*(1), 67–77. https://doi.org/10.1016/j.cmet.2019.05.008

Hawkins, K. A., Dean, D., & Pearlson, G. D. (2004). Alternative forms of the Rey Auditory-Verbal learning test: A review. *Behavioural neurology*, *15*(3-4), 99–107. https://doi.org/10.1155/2004/940191

Hendrie, G. A., Baird, D., Golley, R. K., & Noakes, M. (2017). The CSIRO healthy diet score: An online survey to estimate compliance with the Australian dietary guidelines. *Nutrients*, *9*(1), 47. https://doi.org/10.3390/nu9010047

Herrero Lozano, R., & Fillat Ballesteros, J. C. (2006). Estudio sobre el desayuno y el rendimiento escolar en un grupo de adolescentes. *Nutrición Hospitalaria*, *21*(3), 346–352. https://scielo.isciii.es/scielo.php?script=sci_arttext&pid=S0212-16112006000300009

Hochberg, Z. E., & Konner, M. (2020). Emerging adulthood, a pre-adult life-history stage. *Frontiers in Endocrinology*, *10*, 918. https://doi.org/10.3389/fendo.2019.00918

Hollar, D., Messiah, S. E., Lopez-Mitnik, G., Hollar, T. L., Almon, M., & Agatston, A. S. (2010). Healthier options for public schoolchildren program improves weight and blood pressure in 6-to 13-year olds. *Journal of the American Dietetic Association*, *110*(2), 261–267. https://doi.org/10.1016/j.jada.2009.10.029

Hosking, D. E., Eramudugolla, R., Cherbuin, N., & Anstey, K. J. (2019). MIND not Mediterranean diet related to 12-year incidence of cognitive impairment in an Australian longitudinal cohort study. *Alzheimer's & Dementia*, *15*(4), 581–589. https://doi.org/10.1016/j.jalz.2018.12.011

Howarth, N. C., Huang, T. T., Roberts, S. B., Lin, B. H., & McCrory, M. A. (2007). Eating patterns and dietary composition in relation to BMI in younger and older adults. *International Journal of Obesity*, *31*(4), 675–684. https://doi.org/10.1038/sj.ijo.0803456

Imamura, F., Micha, R., Khatibzadeh, S., Fahimi, S., Shi, P., Powles, J., & Mozaffarian, D. (2015). Dietary quality among men and women in 187 countries in 1990 and 2010: A systematic assessment. *The Lancet Global Health*, *3*(3), e132–e142. https://doi.org/10.1016/S2214-109X(14)70381-X

Imlach, A. R., Ward, D. D., Stuart, K. E., Summers, M. J., Valenzuela, M. J., King, A. E., Saunders, N. L., Summers, J., Srikanth, V. K., Robinson, A., & Vickers, J. C. (2017).

Age is no barrier: Predictors of academic success in older learners. *NPJ Science of Learning*, *2*(1), 13.

International Agency for Research on Cancer. (2015). *IARC monographs evaluate consumption of red meat and processed meat* [Press release], 240. https://www.iarc.who.int/wp-content/uploads/2018/07/pr240_E.pdf

International Agency for Research on Cancer. (2021). *The nutri-score: A science-based front-of-pack nutrition label: Helping consumers make healthier food choice* [Evidence Summary Brief], 2. https://www.iarc.who.int/wp-content/uploads/2021/09/IARC_Evidence_Summary_Brief_2.pdf

Islam, M. K., Islam, Y. M., & Hoque, M. S. (2014). Poor academic achievement of university students: Problems and solutions. *ULAB Journal of Science and Engineering*, *5*(1), 18–25.

Iwata, N. G., Pham, M., Rizzo, N. O., Cheng, A. M., Maloney, E., & Kim, F. (2011). Trans fatty acids induce vascular inflammation and reduce vascular nitric oxide production in endothelial cells. *PLoS One*, *6*(12), e29600. https://doi.org/10.1371/journal.pone.0029600

Jacka, F. N., Cherbuin, N., Anstey, K. J., Sachdev, P., & Butterworth, P. (2015). Western diet is associated with a smaller hippocampus: A longitudinal investigation. *BioMed Central Medicine*, *13*(1), 1–8. https://doi.org/10.1186/s12916-015-0461-x

Jacka, F. N., Pasco, J. A., Mykletun, A., Williams, L. J., Hodge, A. M., O'Reilly, S. L., Nicholson, G. C., Kotowicz, M. A. & Berk, M. (2010). Association of Western and traditional diets with depression and anxiety in women. *American Journal of Psychiatry*, *167*(3), 305–311. https://doi.org/10.1176/appi.ajp.2009.09060881

Jacobs, D. R., & Steffen, L. M. (2003). Nutrients, foods, and dietary patterns as exposures in research: a framework for food synergy. *The American Journal of Clinical Nutrition*, *78*(3), 508S–513S. https://doi.org/10.1093/ajcn/78.3.508S

Jacobs, D. R., Tapsell, L. C., & Temple, N. J. (2011). Food synergy: the key to balancing the nutrition research effort. *Public Health Reviews*, *33*(2), 507–529. https://doi.org/10.1007/BF03391648

Johnson, R. B., & Christensen, L. (2019). *Educational research: Quantitative, qualitative, and mixed approaches*. Sage publications.

Jones, J. M. (2019). Food processing: criteria for dietary guidance and public health? *Proceedings of the Nutrition Society*, *78*(1), 4–18. https://doi.org/10.1017/S0029665118002513

Juul, F., dos Santos Simões, B., Litvak, J., Martinez-Steele, E., Deierlein, A., Vadiveloo, M., & Parekh, N. (2019). Processing level and diet quality of the US grocery cart: Is there an association? *Public Health Nutrition*, *22*(13), 2357–2366. https://doi.org/10.1017/S1368980019001344

Juul, F., Martinez-Steele, E., Parekh, N., Monteiro, C. A., & Chang, V. W. (2018). Ultra-processed food consumption and excess weight among US adults. *British Journal of Nutrition*, *120*(1), 90–100. https://doi.org/10.1017/S0007114518001046

Juul, F., Parekh, N., Martinez-Steele, E., Monteiro, C. A., & Chang, V. W. (2022). Ultra-processed food consumption among US adults from 2001 to 2018. *The American Journal of Clinical Nutrition*, *115*(1), 211–221. https://doi.org/10.1093/ajcn/nqab305

Kane, M. J., Brown, L. H., McVay, J. C., Silvia, P. J., Myin-Germeys, I., & Kwapil, T. R. (2007). For whom the mind wanders, and when: An experience-sampling study of

working memory and executive control in daily life. *Psychological Science, 18*(7), 614–621. https://doi.org/10.1111/j.1467-9280.2007.01948.x

Kanoski, S. E., & Davidson, T. L. (2011). Western diet consumption and cognitive impairment: links to hippocampal dysfunction and obesity. *Physiology & Behavior*, *103*(1), 59–68. https://doi.org/10.1016/j.physbeh.2010.12.003

Kenrick, D. T., Griskevicius, V., Neuberg, S. L., & Schaller, M. (2010). Renovating the pyramid of needs: Contemporary extensions built upon ancient foundations. *Perspectives on Psychological Science, 5*(3), 292–314. https://doi.org/10.1177/1745691610369469

Kent, K., Charlton, K. E., Netzel, M., & Fanning, K. (2017). Food-based anthocyanin intake and cognitive outcomes in human intervention trials: A systematic review. *Journal of Human Nutrition and Dietetics*, *30*(3), 260–274. https://doi.org/10.1111/jhn.12431

Kent, K., Charlton, K. E., Roodenrys, S., Batterham, M., Potter, J., Traynor, V., Gilbert, H., Morgan, O., & Richards, R. (2017). Consumption of anthocyanin-rich cherry juice for 12 weeks improves memory and cognition in older adults with mild-to-moderate dementia. *European Journal of Nutrition, 56*(1), 333–341. https://doi.org/10.1007/s00394-015-1083-y

Knight, A., Bryan, J., Wilson, C., Hodgson, J., & Murphy, K. (2015). A randomised controlled intervention trial evaluating the efficacy of a Mediterranean dietary pattern on cognitive function and psychological wellbeing in healthy older adults: The MedLey study. *BioMed Central Geriatrics*, *15*(1), 1–14. https://doi.org/10.1186/s12877-015-0054-8

Krikorian, R., Nash, T. A., Shidler, M. D., Shukitt-Hale, B., & Joseph, J. A. (2010). Concord grape juice supplementation improves memory function in older adults with mild cognitive impairment. *British Journal of Nutrition*, *103*(5), 730–734. https://doi.org/10.1017/S0007114509992364

Krikorian, R., Shidler, M. D., Nash, T. A., Kalt, W., Vinqvist-Tymchuk, M. R., Shukitt-Hale, B., & Joseph, J. A. (2010). Blueberry supplementation improves memory in older adults. *Journal of Agricultural and Food Chemistry*, *58*(7), 3996–4000. https://doi.org/10.1021/jf9029332

Krivanek, T. J., Gale, S. A., McFeeley, B. M., Nicastri, C. M., & Daffner, K. R. (2021). Promoting successful cognitive aging: A ten-year update. *Journal of Alzheimer's Disease*, *81*(3), 871–920. https://doi.org/10.3233/JAD-201462

Lam, M. C. L., & Adams, J. (2017). Association between home food preparation skills and behaviour, and consumption of ultra-processed foods: Cross-sectional analysis of the UK National Diet and nutrition survey (2008–2009). *International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), 1–7. https://doi.org/10.1186/s12966-017-0524-9

Lane, M. M., Davis, J. A., Beattie, S., Gómez-Donoso, C., Loughman, A., O'Neil, A., Jacka, F., Berk, M., Page, R., Marx, W., & Rocks, T. (2021). Ultraprocessed food and chronic noncommunicable diseases: A systematic review and meta-analysis of 43 observational studies. *Obesity Reviews*, *22*(3), e13146. https://doi.org/10.1111/obr.13146

Lanuza, F., Morales, G., Hidalgo-Rasmussen, C., Balboa-Castillo, T., Ortiz, M. S., Belmar, C., & Muñoz, S. (2022). Association between eating habits and quality of life among Chilean university students. *Journal of American College Health*, *70*(1), 280–286. https://doi.org/10.1080/07448481.2020.1741593

Leber, W., Evans, D., Petersen, K., & Raymond, T. (2022). Does the consumption of a high flavonoid diet improve cognitive function in adults? *Evidence-Based Practice*, *25*(3), 41–43. https://doi.org/10.1097/EBP.0000000000001427

Lee-Kwan, S. H., Moore, L. V., Blanck, H. M., Harris, D. M., & Galuska, D. (2017). Disparities in state-specific adult fruit and vegetable consumption—United States, 2015. *Morbidity*

and Mortality Weekly Report, *66*(45), 1241–1247. http://dx.doi.org/10.15585/mmwr.mm6645a1external icon

Lee, J., Pase, M., Pipingas, A., Raubenheimer, J., Thurgood, M., Villalon, L., Macpherson, H., Gibbs, A., & Scholey, A. (2015). Switching to a 10-day Mediterranean-style diet improves mood and cardiovascular function in a controlled crossover study. *Nutrition, 31*(5), 647–652. https://doi.org/10.1016/j.nut.2014.10.008

Leffa, P. S., Hoffman, D. J., Rauber, F., Sangalli, C. N., Valmórbida, J. L., & Vitolo, M. R. (2020). Longitudinal associations between ultra-processed foods and blood lipids in childhood. *British Journal of Nutrition*, *124*(3), 341–348. https://doi.org/10.1017/S0007114520001233

Lehtisalo, J., Levälahti, E., Lindström, J., Hänninen, T., Paajanen, T., Peltonen, M., Antikainen, R., Laatikainen, T., Strandberg, T., Soininen, H., Tuomilehto, J., Kivipelto, M., & Ngandu, T. (2019). Dietary changes and cognition over 2 years within a multidomain intervention trial—The Finnish Geriatric Intervention Study to Prevent Cognitive Impairment and Disability (FINGER). *Alzheimer's & Dementia, 15*(3), 410–417. https://doi.org/10.1016/j.jalz.2018.10.001

Lemos, T. C., Coutinho, G. M., Silva, L. A., Stariolo, J. B., Campagnoli, R. R., Oliveira, L., Pereira, M. G., Mota, B. E., Souza, G. G., Canella, D. S., Khandpur, N. & David, I. A. (2022). Ultra-processed foods elicit higher approach motivation than unprocessed and minimally processed foods. *Frontiers in Public Health*, *10*, 891546. https://doi.org/10.3389/fpubh.2022.891546

Leo, E. E. M., & Campos, M. R. S. (2020). Effect of ultra-processed diet on gut microbiota and thus its role in neurodegenerative diseases. *Nutrition*, *71*, 110609. https://doi.org/10.1016/j.nut.2019.110609

Lesani, A., Mohammadpoorasl, A., Javadi, M., Esfeh, J. M., & Fakhari, A. (2016). Eating breakfast, fruit and vegetable intake and their relation with happiness in college students. *Eating and Weight Disorders, 21*(4), 645–651. https://doi.org/10.1007/s40519-016-0261-0

Lezak, M. D. (1983). *Neuropsychological assessment*, (2nd ed.). Oxford University Press.

Lila, M. A. (2004). Anthocyanins and human health: An in vitro investigative approach. *Journal of Biomedicine and Biotechnology*, *2004*(5), 306–313. https://doi.org/10.1155/S111072430440401X

Liquori, T., Koch, P. D., Contento, I. R., & Castle, J. (1998). The cookshop program: outcome evaluation of a nutrition education program linking lunchroom food experiences with classroom cooking experiences. *Journal of Nutrition Education*, *30*(5), 302–313. https://doi.org/10.1016/S0022-3182(98)70339-5

Liu, R. H. (2003). Health benefits of fruit and vegetables are from additive and synergistic combinations of phytochemicals. *The American Journal of Clinical Nutrition*, *78*(3), 517S–520S. https://doi.org/10.1093/ajcn/78.3.517S

Livingston, G., Huntley, J., Sommerlad, A., Ames, D., Ballard, C., Banerjee, S., Brayne, C., Burns, A., Cohen-Mansfield, J., Cooper, C., Costafreda, S. G., Dias, A., Fox, N., Gitlin, L., Howard, R., Kales, H. C., Kivimäki, M., Larson, E. B., Ogunniyi, A., ... & Mukadam, N. (2020). Dementia prevention, intervention, and care: 2020 report of the Lancet Commission. *The Lancet*, *396*(10248), 413–446. https://doi.org/10.1016/S0140-6736(20)30367-6

Loughrey, D. G., Lavecchia, S., Brennan, S., Lawlor, B. A., & Kelly, M. E. (2017). The impact of the Mediterranean diet on the cognitive functioning of healthy older adults: A

systematic review and meta-analysis. *Advances in Nutrition*, *8*(4), 571–586. https://doi.org/10.3945/an.117.015495

Lunsford, J. (2022). *Food neophobia factors in college students* [Doctoral dissertation, Rush University]. ProQuest Dissertations & Theses Global. https://www.proquest.com/openview/165ec89b148c3d7e6edbaf52c7f1c98b/1.pdf?cbl=18750&diss=y&pq-origsite=gscholar

Lustig, R. H. (2017). Processed food—an experiment that failed. *JAMA Pediatrics*, *171*(3), 212–214. https://doi.org/10.1001/jamapediatrics.2016.4136

Machado, P. P., Steele, E. M., Levy, R. B., Sui, Z., Rangan, A., Woods, J., Gill, T., Scrinis, G., & Monteiro, C. A. (2019). Ultra-processed foods and recommended intake levels of nutrients linked to non-communicable diseases in Australia: Evidence from a nationally representative cross-sectional study. *British Medical Journal Open, 9*(8), e029544. https://doi.org/10.1136/bmjopen-2019-029544

Maciel, B. L. L., Lyra, C. D. O., Gomes, J. R. C., Rolim, P. M., Gorgulho, B. M., Nogueira, P. S., Rodrigues, P. R. M., Da Silva, T. F., Martins, F. A., Dalamaria, T., Santos, T. S. S., Höfelmann, D. A., Crispim, S. P., Slater, B., Rmalho, A. A., & Marchioni, D. M. (2022). Food insecurity and associated factors in Brazilian undergraduates during the COVID-19 pandemic. *Nutrients, 14*(2), 358. https://doi.org/10.3390/nu14020358

Makero, S. C., & Bii, J. K. (2018). Nutrition and its Effects on Learning among the Early Childhood and Primary Education (EPE) Children of Sigor Location. *African Journal of Education, Science and Technology, 2*(2), 103–108. https://doi.org/10.2022/ajest.v2i2.288

Margină, D., Ungurianu, A., Purdel, C., Nițulescu, G. M., Tsoukalas, D., Sarandi, E., Thanasoula, M., Burykina, T. I., Tekos, F., Buha, A., Nikitovic, D., Kouretas, D., &

Tsatsakis, A. M. (2020). Analysis of the intricate effects of polyunsaturated fatty acids and polyphenols on inflammatory pathways in health and disease. *Food and Chemical Toxicology*, *143*, 111558. https://doi.org/10.1016/j.fct.2020.111558

Marino, M., Puppo, F., Del Bo', C., Vinelli, V., Riso, P., Porrini, M., & Martini, D. (2021). A systematic review of worldwide consumption of ultra-processed foods: Findings and criticisms. *Nutrients, 13*(8), 2778. https://doi.org/10.3390/nu13082778

Martin, K. E. (2022). *Helping high school students succeed academically by meeting their more basic needs* [Doctoral dissertation, University of South Carolina]. Scholar Commons. https://scholarcommons.sc.edu/etd/6760

Martínez Steele, E., Baraldi, L. G., da Costa Louzada, M. L., Moubarac, J. C., Mozaffarian, D., & Monteiro, C. A. (2016). Ultra-processed foods and added sugars in the US diet: Evidence from a nationally representative cross-sectional study. *British Medical Journal Open*, *6*(3), e009892. https://doi.org/10.1136/bmjopen-2015-009892

Martínez Steele, E., Juul, F., Neri, D., Rauber, F., & Monteiro, C. A. (2019). Dietary share of ultra-processed foods and metabolic syndrome in the US adult population. *Preventive Medicine*, *125*, 40–48. https://doi.org/10.1016/j.ypmed.2019.05.004

Martínez Steele, E., Khandpur, N., da Costa Louzada, M. L., & Monteiro, C. A. (2020). Association between dietary contribution of ultra-processed foods and urinary concentrations of phthalates and bisphenol in a nationally representative sample of the US population aged 6 years and older. *PLoS One*, *15*(7), e0236738. https://doi.org/10.1371/journal.pone.0236738

Martínez Steele, E., Popkin, B. M., Swinburn, B., & Monteiro, C. A. (2017). The share of ultra-processed foods and the overall nutritional quality of diets in the US: evidence from a

nationally representative cross-sectional study. *Population Health Metrics*, *15*(1), 1–11. https://doi.org/10.1186/s12963-017-0119-3

Martínez-Lapiscina, E. H., Clavero, P., Toledo, E., Estruch, R., Salas-Salvadó, J., San Julián, B., Sanchez-Tainta, A., Ros, E., Valls-Pedret, C., & Martinez-Gonzalez, M. Á. (2013). Mediterranean diet improves cognition: The PREDIMED-NAVARRA randomised trial. *Journal of Neurology, Neurosurgery & Psychiatry*, *84*(12), 1318–1325. https://doi.org/10.1136/jnnp-2012-304792

Martinez-Perez, C., San-Cristobal, R., Guallar-Castillon, P., Martínez-González, M. Á., Salas-Salvadó, J., Corella, D., Castañer, O., Martinez, J. A., Alonso-Gómez, Á. M., Wärnberg, J., Vioque, J., Romaguera, D., López-Miranda, J., Estruch, R., Tinahones, F. J., Lapetra, J., Serra-Majem, L., Bueno-Cavanillas, A., Tur, J. A., & Daimiel, L. (2021). Use of different food classification systems to assess the association between ultra-processed food consumption and cardiometabolic health in an elderly population with metabolic syndrome (PREDIMED-Plus Cohort). *Nutrients*, *13*(7), 2471. https://doi.org/10.3390/nu13072471

Marx, W., Lane, M., Hockey, M., Aslam, H., Berk, M., Walder, K., Borsini, A., Firth, J., Pariante, C. M., Berding, K., Cryan, J. F., Clarke, G., Craig, J. M., Su, K., Mischoulon, D., Gomez-Pinilla, F., Foster, J. A., Cani, P. D., Thuret, S., & Jacka, F. N. (2021). Diet and depression: Exploring the biological mechanisms of action. *Molecular Psychiatry*, *26*(1), 134–150. https://doi.org/10.1038/s41380-020-00925-x

Maslow, A. H. (1943). A theory of human motivation. *Psychological Review*, *50*(4), 370. http://psychclassics.yorku.ca/Maslow/motivation.htm

Mastroiacovo, D., Kwik-Uribe, C., Grassi, D., Necozione, S., Raffaele, A., Pistacchio, L., Righetti, R., Bocale, R., Lechiara, M. C., Marini, C., Ferri, C., & Desideri, G. (2015).

Cocoa flavanol consumption improves cognitive function, blood pressure control, and metabolic profile in elderly subjects: The Cocoa, Cognition, and Aging (CoCoA) Study—a randomized controlled trial. *The American Journal of Clinical Nutrition*, *101*(3), 538–548. https://doi.org/10.3945/ajcn.114.092189

McEvoy, C. T., Guyer, H., Langa, K. M., & Yaffe, K. (2017). Neuroprotective diets are associated with better cognitive function: the health and retirement study. *Journal of the American Geriatrics Society*, *65*(8), 1857–1862. https://doi.org/10.1111/jgs.14922

McNamara, R. K., Kalt, W., Shidler, M. D., McDonald, J., Summer, S. S., Stein, A. L., Stover, A. N., & Krikorian, R. (2018). Cognitive response to fish oil, blueberry, and combined supplementation in older adults with subjective cognitive impairment. *Neurobiology of Aging*, *64*, 147–156. https://doi.org/10.1016/j.neurobiolaging.2017.12.003

Mello Rodrigues, V., Bray, J., Fernandes, A. C., Luci Bernardo, G., Hartwell, H., Secchi Martinelli, S., Lazzarin Uggioni, P., Barletto Cavalli, S., & Proença, R. P. D. C. (2019). Vegetable consumption and factors associated with increased intake among college students: A scoping review of the last 10 years. *Nutrients*, *11*(7), 1634. https://doi.org/10.3390/nu11071634

Melo, H. M., Silva, L. E., Natalia, M., & Grillo, C. A. (2022). The Impact of Obesity on Cognitive Function. *Frontiers in Neuroscience*, *16*, 950. https://doi.org/10.3389/fnins.2022.916243

Merriam, S. B. & Tisdell, E.J. (2016). *Qualitative research: A guide to design and implementation* (4th ed.). Jossey-Bass.

Mesas, A. E., González, A. D., de Andrade, S. M., Martínez-Vizcaíno, V., López-Gil, J. F., & Jiménez-López, E. (2022). Increased consumption of ultra-processed food is associated

with poor mental health in a nationally representative sample of adolescent students in Brazil. *Nutrients*, *14*(24), 5207. https://doi.org/10.3390/nu14245207

Messina, M., Lampe, J. W., Birt, D. F., & Appel, L. J. (2001). Reductionism and the narrowing nutrition perspective: time for reevaluation and emphasis on food synergy. *Journal of the Academy of Nutrition and Dietetics*, *101*(12), 1416. https://doi.org/10.1016/S0002-8223(01)00342-X

Miranda, A. R., Cortez, M. V., Scotta, A. V., & Soria, E. A. (2022). Dietary intake of polyphenols enhances executive/attentional functioning and memory with an improvement of the milk lipid profile of postpartum women from Argentina. *Journal of Intelligence*, *10*(2), 33. https://doi.org/10.3390/jintelligence10020033

Monteiro, C. A., Cannon, G., Lawrence, M., Costa Louzada, M. D., & Pereira Machado, P. (2019). *Ultra-processed foods, diet quality, and health using the Nova classification system*. Food and Agriculture Organization of the United Nations. https://www.fao.org/publications/card/en/c/CA5644EN/

Monteiro, C. A., Cannon, G., Levy, R. B., Moubarac, J. C., Louzada, M. L., Rauber, F., Khandpur, N., Cediel, G., Neri, D., Martinez-Steele, E. and Baraldi, L. G., & Jaime, P. C. (2019). Ultra-processed foods: what they are and how to identify them. *Public Health Nutrition*, *22*(5), 936-941. https://doi.org/10.1017/S1368980018003762

Monteiro, C. A., Cannon, G., Levy, R., Moubarac, J. C., Jaime, P., Martins, A. P., Canella, D., Louzada, M., & Parra, D. (2016). Nova: The star shines bright. *World Nutrition*, *7*(1-3), 28–38. https://worldnutritionjournal.org/index.php/wn/article/view/5

Monteiro, C. A., Cannon, G., Moubarac, J. C., Levy, R. B., Louzada, M. L. C., & Jaime, P. C. (2018). The UN Decade of Nutrition, the Nova food classification and the trouble with

ultra-processing. *Public Health Nutrition*, *21*(1), 5–17. https://doi.org/10.1017/S1368980017000234

Monteiro, C. A., Levy, R. B., Claro, R. M., Castro, I. R. R. D., & Cannon, G. (2010). A new classification of foods based on the extent and purpose of their processing. *Journal of Public Health*, *26*, 2039–2049. https://doi.org/10.1590/s0102-311x2010001100005

Monteiro, C. A., Moubarac, J. C., Cannon, G., Ng, S. W., & Popkin, B. (2013). Ultra-processed products are becoming dominant in the global food system. *Obesity Reviews*, *14*, 21–28. https://doi.org/10.1111/obr.12107

Monteiro, C. A., Moubarac, J. C., Levy, R. B., Canella, D. S., da Costa Louzada, M. L., & Cannon, G. (2018). Household availability of ultra-processed foods and obesity in nineteen European countries. *Public Health Nutrition*, *21*(1), 18–26. https://doi.org/10.1017/S1368980017001379

Moore, L. V., Thompson, F. E., & Demissie, Z. (2017). Percentage of youth meeting federal fruit and vegetable intake recommendations, Youth Risk Behavior Surveillance System, United States and 33 states, 2013. *Journal of the Academy of Nutrition and Dietetics, 117*(4), 545–553. https://doi.org/10.1016/j.jand.2016.10.012

Morris, M. C., Wang, Y., Barnes, L. L., Bennett, D. A., Dawson-Hughes, B., & Booth, S. L. (2018). Nutrients and bioactives in green leafy vegetables and cognitive decline: Prospective study. *Neurology*, *90*(3), e214–e222. https://doi.org/10.1212/WNL.0000000000004815

Moubarac, J. C., Batal, M., Louzada, M. L., Steele, E. M., & Monteiro, C. A. (2017). Consumption of ultra-processed foods predicts diet quality in Canada. *Appetite*, *108*, 512–520. https://doi.org/10.1016/j.appet.2016.11.006

Muijs, D. (2010). *Doing quantitative research in education with SPSS*. Sage.

Munt, A. E., Partridge, S. R., & Allman-Farinelli, M. (2017). The barriers and enablers of healthy eating among young adults: A missing piece of the obesity puzzle: A scoping review. *Obesity Reviews*, *18*(1), 1–17. https://doi.org/10.1111/obr.12472

Murray, C. J., Atkinson, C., Bhalla, K., Birbeck, G., Burstein, R., Chou, D., Dellavalle, R., Danaei, G., Ezzati, M., Fahimi, A., Flaxman, D., Foreman, Gabriel, S., Gakidou, E., Kassebaum, N., Khatibzadeh, S., Lim, S., Lipschultz, S., E., London, S., & Murray. (2013). The state of US health, 1990–2010: Burden of diseases, injuries, and risk factors. *JAMA*, *310*(6), 591–606. https://doi.org/10.1001/jama.2013.13805

Na, X., Xi, M., Zhou, Y., Yang, J., Zhang, J., Xi, Y., Yang, Y., Yang, H., & Zhao, A. (2022). Association of dietary sodium, potassium, sodium/potassium, and salt with objective and subjective cognitive function among the elderly in China: A prospective cohort study. *Global Transitions*, 4, 28–39. https://doi.org/10.1016/j.glt.2022.10.002

National Research Council. (1990). *Diet and health: implications for reducing chronic disease risk*. National Academies Press. https://doi.org/10.17226/1222

Newgard, C. D., & Haukoos, J. S. (2007). Advanced statistics: Missing data in clinical research—part 2: multiple imputation. *Academic Emergency Medicine*, *14*(7), 669–678. https://doi.org/10.1197/j.aem.2006.11.038

Neumark-Sztainer, D., Story, M., Resnick, M. D., & Blum, R. W. (1996). Correlates of inadequate fruit and vegetable consumption among adolescents. *Preventative Medicine*, *25*, 497–505 https://doi.org/10.1006/pmed.1996.0082

Noble, E. E., Hsu, T. M., & Kanoski, S. E. (2017). Gut to brain dysbiosis: Mechanisms linking western diet consumption, the microbiome, and cognitive impairment. *Frontiers in Behavioral Neuroscience*, *11*, 9. https://doi.org/10.3389/fnbeh.2017.00009

Nyaradi, A., Foster, J. K., Hickling, S., Li, J., Ambrosini, G. L., Jacques, A., & Oddy, W. H. (2014). Prospective associations between dietary patterns and cognitive performance during adolescence. *Journal of Child Psychology and Psychiatry*, *55*(9), 1017–1024. https://doi.org/10.1111/jcpp.12209

O'Keefe, J. H., Gheewala, N. M., & O'Keefe, J. O. (2008). Dietary strategies for improving post-prandial glucose, lipids, inflammation, and cardiovascular health. *Journal of the American College of Cardiology*, *51*(3), 249–255. https://doi.org/10.1016/j.jacc.2007.10.016

Ornish, D., Scherwitz, L. W., Billings, J. H., Gould, K. L., Merritt, T. A., Sparler, S., Armstrong, W. T., Ports, T. A., Kirkeeide, R. L., Hogeboom, C., & Brand, R. J. (1998). Intensive lifestyle changes for reversal of coronary heart disease. *JAMA*, *280*(23), 2001–2007. https://doi.org/10.1001/jama.280.23.2001

Osendarp, S. J. M., Baghurst, K. I., Bryan, J., Calvaresi, E., Hughes, D., Hussaini, M., Karyadi, E., Jan-Willem van Klinken, B., van der Knaap, H. C. M., Lukito, W., Mikarsa, H., Transler, C., & Wilson, C. (2007). Effect of a 12-mo micronutrient intervention on learning and memory in well-nourished and marginally nourished school-aged children: 2 parallel, randomized, placebo-controlled studies in Australia and Indonesia. *The American Journal of Clinical Nutrition*, *86*(4), 1082–1093. https://doi.org/10.1093/ajcn/86.4.1082

Ozawa, M., Shipley, M., Kivimaki, M., Singh-Manoux, A., & Brunner, E. J. (2017). Dietary pattern, inflammation and cognitive decline: the Whitehall II prospective cohort study. *Clinical Nutrition*, *36*(2), 506–512. https://doi.org/10.1016/j.clnu.2016.01.013

Pagliai, G., Dinu, M., Madarena, M. P., Bonaccio, M., Iacoviello, L., & Sofi, F. (2021). Consumption of ultra-processed foods and health status: a systematic review and meta-

analysis. *British Journal of Nutrition*, *125*(3), 308–318. https://doi.org/10.1017/S0007114520002688

Pan American Health Organization. (2015). *Ultra-processed food and drink products in Latin America: Trends, impact on obesity, policy implications*. https://iris.paho.org/handle/10665.2/7699

Parsons, K., Neptune, L., Sullivan, A., & McNamara, J. (2022). P075 Differences in Diet Quality and College Students' Health-Related Quality of Life. *Journal of Nutrition Education and Behavior*, *54*(7), S53. https://doi.org/10.1016/j.jneb.2022.04.115

Payne-Sturges, D. C., Tjaden, A., Caldeira, K. M., Vincent, K. B., & Arria, A. M. (2018). Student hunger on campus: Food insecurity among college students and implications for academic institutions. *American Journal of Health Promotion*, *32*(2), 349–354. https://doi.org/10.1177/0890117117719620

Peltzer, K., & Pengpid, S. (2015). Correlates of healthy fruit and vegetable diet in students in low, middle and high income countries. *International Journal of Public Health*, *60*(1), 79–90. https://doi.org/10.1007/s00038-014-0631-1

Pérez-Jiménez, J., Neveu, V., Vos, F., & Scalbert, A. (2010). Identification of the 100 richest dietary sources of polyphenols: an application of the Phenol-Explorer database. *European Journal of Clinical Nutrition*, *64*(3), S112–S120. https://doi.org/10.1038/ejcn.2010.221

Pfreundschuh, S. (2022). Making A Dent in the Obesity Equation via Coupling Sugar-Sweetened Beverage Taxes with Fruit and Vegetable Subsidies. *Aresty Rutgers Undergraduate Research Journal*, *1*(4), 1–16. https://doi.org/10.14713/arestyrurj.v1i4.209

Philip, P., Sagaspe, P., Taillard, J., Mandon, C., Constans, J., Pourtau, L., Pouchieu, C., Angelino, D., Mena, P., Martini, D., Del Rio, D., & Vauzour, D. (2019). Acute intake of a grape and blueberry polyphenol-rich extract ameliorates cognitive performance in

healthy young adults during a sustained cognitive effort. *Antioxidants*, *8*(12), 650. https://doi.org/10.3390/antiox8120650

Pilato, I. B., Beezhold, B., & Radnitz, C. (2022). Diet and lifestyle factors associated with cognitive performance in college students. *Journal of American College Health*, *70*(7), 2230–2236. https://doi.org/10.1080/07448481.2020.1847118

Pistollato, F., & Battino, M. (2014). Role of plant-based diets in the prevention and regression of metabolic syndrome and neurodegenerative diseases. *Trends in Food Science & Technology*, *40*(1), 62–81. https://doi.org/10.1016/j.tifs.2014.07.012

Pokhrel, S., & Chhetri, R. (2021). A literature review on impact of COVID-19 pandemic on teaching and learning. *Higher Education for the Future*, *8*(1), 133–141. https://doi.org/10.1177/2347631120983481

Pontoppidan, J. R. N., Nielsen, E. E., Olsen, M. H., Skjødt, M. K., Christensen, J. O., Raymond, I. E., Møller, S. H., Boas Soja, A. M., & Gæde, P. H. (2024). A multidisciplinary, shared care clinic using personalized medicine and coordinated care in patients with concomitant type 2 diabetes and cardiovascular disease. Protocol and baseline characteristics. *Preventive Medicine Reports*, *38*, 102594. https://doi.org/10.1016/j.pmedr.2024.102594

Prieto-González, P., Sánchez-Infante, J., & Fernández-Galván, L. M. (2022). Association between adherence to the Mediterranean diet and anthropometric and health variables in college-aged males. *Nutrients*, *14*(17), 3471. https://doi.org/10.3390/nu14173471

Psaltopoulou, T., Sergentanis, T. N., Panagiotakos, D. B., Sergentanis, I. N., Kosti, R., & Scarmeas, N. (2013). Mediterranean diet, stroke, cognitive impairment, and depression: a meta-analysis. *Annals of Neurology*, *74*(4), 580–591. https://doi.org/10.1002/ana.23944

Rajaram, S., Jones, J., & Lee, G. J. (2019). Plant-based dietary patterns, plant foods, and age-related cognitive decline. *Advances in Nutrition*, *10*(Supplement_4), S422–S436. https://doi.org/10.1093/advances/nmz081

Rancière, F., Lyons, J. G., Loh, V. H., Botton, J., Galloway, T., Wang, T., Shaw, J. E., & Magliano, D. J. (2015). Bisphenol A and the risk of cardiometabolic disorders: a systematic review with meta-analysis of the epidemiological evidence. *Environmental Health*, *14*(1), 1–23. https://doi.org/10.1186/s12940-015-0036-5

Rauber, F., da Costa Louzada, M. L., Martínez Steele, E., de Rezende, L. F., Millett, C., Monteiro, C. A., & Levy, R. B. (2019). Ultra-processed foods and excessive free sugar intake in the UK: A nationally representative cross-sectional study. *British Medical Journal Open*, *9*(10), e027546. https://doi.org/10.1136/bmjopen-2018-027546

Rauber, F., de Costa Louzada, M. L., Martínez Steele, E., Millett, C., Monteiro, C. A., & Levy, R. B. (2018). Ultra-processed food consumption and chronic non-communicable diseases-related dietary nutrient profile in the UK (2008–2014). *Nutrients*, *10*(5), 587. https://doi.org/10.3390/nu10050587

Rauber, F., Martínez Steele, E., de Costa Louzada, M. L., Millett, C., Monteiro, C. A., & Levy, R. B. (2020). Ultra-processed food consumption and indicators of obesity in the United Kingdom population (2008-2016). *PLoS One*, *15*(5), e0232676. https://doi.org/10.1371/journal.pone.0232676

Rey, A. (1958). *L'examen clinique en psychologie*. Presses Universitaires de France.

Ricardo, A. T., Herz, N., Halpern, D., Tracy, J., & Kahana, M. J. (2022). *Multi-trial free recall for evaluating memory*. PsyArXiv. https://doi.org/10.31234/osf.io/d7za2

Rico-Campà, A., Martínez-González, M. A., Alvarez-Alvarez, I., de Deus Mendonça, R., de la Fuente-Arrillaga, C., Gómez-Donoso, C., & Bes-Rastrollo, M. (2019). Association

between consumption of ultra-processed foods and all cause mortality: SUN prospective cohort study. *British Medical Journal*, *365*, l1949. https://doi.org/10.1136/bmj.l1949

Riva, D., Nichelli, F., & Devoti, M. (2000). Developmental aspects of verbal fluency and confrontation naming in children. *Brain and Language*, *71*(2), 267–284. https://doi.org/10.1006/brln.1999.2166

Rothwell, J. A., Perez-Jimenez, J., Neveu, V., Medina-Remon, A., M'hiri, N., García-Lobato, P., Manach, C., Knox, C., Eisner, R., Wishart, D. S. & Scalbert, A. (2013). Phenol-Explorer 3.0: a major update of the Phenol-Explorer database to incorporate data on the effects of food processing on polyphenol content. *Database*, *2013*, 1–8. https://doi.org/10.1093/database/bat070

Ruff, R. M., Light, R. H., Parker, S. B., & Levin, H. S. (1996). Benton controlled oral word association test: reliability and updated norms. *Archives of Clinical Neuropsychology*, *11*(4), 329–338. https://doi.org/10.1016/0887-6177(95)00033-X

Ryan, J. J., Geisser, M. E., Randall, D. M., & Georgemiller, R. J. (1986). Alternate form reliability and equivalency of the Rey Auditory-Verbal Learning Test. *Journal of Clinical and Experimental Neuropsychology*, *8*(5), 611–616. https://doi.org/10.1080/01688638608405179

Sanchez-Aguadero, N., Recio-Rodriguez, J. I., Patino-Alonso, M. C., Mora-Simon, S., Alonso-Dominguez, R., Sanchez-Salgado, B., Gomez-Marcos, M. A., & Garcia-Ortiz, L. (2020). Postprandial effects of breakfast glycaemic index on cognitive performance among young, healthy adults: A crossover clinical trial. *Nutritional Neuroscience*, *23*(1), 1–7. https://doi.org/10.1080/1028415X.2018.1461459

Sánchez-Ojeda, M. A., & Luna-Bertos, E. D. (2015). Hábitos de vida saludable en la población universitaria. *Nutrición hospitalaria*, *31*(5), 1910-1919. https://dx.doi.org/10.3305/nh.2015.31.5.8608

Savas, H. B., Gultekin, F., & Doguc, D. K. (2017). Effects of nutrition style on neuro-behavior. *Biomedical Research*, *28*(11), 5003–5007. https://www.alliedacademies.org/abstract/effects-of-nutrition-style-on-neurobehavior-7601.html

Schanzenbach, D. W., & Zaki, M. (2014). *Expanding the school breakfast program: Impacts on children's consumption, nutrition and health* (Working Paper No. w20308). National Bureau of Economic Research. https://doi.org/10.3386/w20308

Schmidt, M. (1996). *Rey Auditory-Verbal learning test: A handbook*. Western Psychological Services.

Schnabel, L., Kesse-Guyot, E., Allès, B., Touvier, M., Srour, B., Hercberg, S., Buscail, C., & Julia, C. (2019). Association between ultraprocessed food consumption and risk of mortality among middle-aged adults in France. *JAMA Internal Medicine*, *179*(4), 490–498. https://doi.org/10.1001/jamainternmed.2018.7289

Schnettler, B., Orellana, L., Lobos, G., Miranda, H., Sepúlveda, J., Etchebarne, S., Mora, M., Adasme-Berríos, C., & Grunert, K. G. (2015). Relationship between the domains of the Multidimensional Students' Life Satisfaction Scale, satisfaction with food-related life and happiness in university students. *Nutrición hospitalaria*, *31*(6), 2752–2763. https://doi.org/10.3305/nh.2015.31.6.8593

Schulte, E. M., Avena, N. M., & Gearhardt, A. N. (2015). Which foods may be addictive? The roles of processing, fat content, and glycemic load. *PloS One*, *10*(2), e0117959. https://doi.org/10.1371/journal.pone.0117959

Schum, R. L., Sivan, A. B., & Benton, A. (1989). Multilingual aphasia examination: Norms for children. *The Clinical Neuropsychologist*, *3*(4), 375–383. https://doi.org/10.1080/13854048908401486

Serrano, S. E., Braun, J., Trasande, L., Dills, R., & Sathyanarayana, S. (2014). Phthalates and diet: A review of the food monitoring and epidemiology data. *Environmental Health*, *13*(1), 1–14. https://doi.org/10.1186/1476-069X-13-43

Shahidi, F. (2009). Nutraceuticals and functional foods: whole versus processed foods. *Trends in Food Science & Technology*, *20*(9), 376–387. https://doi.org/10.1016/j.tifs.2008.08.004

Shakersain, B., Rizzuto, D., Larsson, S. C., Faxén-Irving, G., Fratiglioni, L., & Xu, W. L. (2018). The Nordic prudent diet reduces risk of cognitive decline in the Swedish older adults: A population-based cohort study. *Nutrients*, *10*(2), 229. https://doi.org/10.3390/nu10020229

Shakersain, B., Santoni, G., Larsson, S. C., Faxén-Irving, G., Fastbom, J., Fratiglioni, L., & Xu, W. (2016). Prudent diet may attenuate the adverse effects of Western diet on cognitive decline. *Alzheimer's & Dementia*, *12*(2), 100–109. https://doi.org/10.1016/j.jalz.2015.08.002

Shan, Z., Rehm, C. D., Rogers, G., Ruan, M., Wang, D. D., Hu, F. B., Mozaffarian, D., Zhang, F. F., & Bhupathiraju, S. N. (2019). Trends in dietary carbohydrate, protein, and fat intake and diet quality among US adults, 1999-2016. *JAMA*, *322*(12), 1178–1187. https://doi.org/10.1001/jama.2019.13771

Shao, Z., Janse, E., Visser, K., & Meyer, A. S. (2014). What do verbal fluency tasks measure? Predictors of verbal fluency performance in older adults. *Frontiers in Psychology*, *5*, 772. https://doi.org/10.3389/fpsyg.2014.00772

Shapiro, D. M., & Harrison, D. W. (1990). Alternate forms of the AVLT: A procedure and test of form equivalency. *Archives of Clinical Neuropsychology, 5*(4), 405–410. https://doi.org/10.1016/0887-6177(90)90018-K

Shapiro, J. P., & Stefkovich, J. A. (2016). *Ethical leadership and decision making in education: Applying theoretical perspectives to complex dilemmas*. Routledge.

Shi, Y., Grech, A., & Allman-Farinelli, M. (2022). Diet quality among students attending an Australian university is compromised by food insecurity and less frequent intake of home cooked meals: A cross-sectional survey using the validated Healthy Eating Index for Australian Adults (HEIFA-2013). *Nutrients, 14*(21), 4522. https://doi.org/10.3390/nu14214522

Shim, J. S., Shim, S. Y., Cha, H. J., Kim, J., & Kim, H. C. (2021). Socioeconomic characteristics and trends in the consumption of ultra-processed foods in Korea from 2010 to 2018. *Nutrients, 13*(4), 1120. https://doi.org/10.3390/nu13041120

Small, D. M., & DiFeliceantonio, A. G. (2019). Processed foods and food reward. *Science, 363*(6425), 346–347. https://doi.org/10.1126/science.aav0556

Smerbeck, A., Olson, L. T., Morra, L. F., Raines, J., Schretlen, D. J., & Benedict, R. H. (2023). Effects of repeated administration and comparability of alternate forms for the global neuropsychological assessment (GNA). *Assessment*, *30*(1), 160–170. https://doi.org/10.1177/10731911211045125

Sorhaindo, A., & Feinstein, L. (2006). *What is the relationship between child nutrition and school outcomes?* [Wider Benefits of Learning Research Report No. 18]. Centre for Research on the Wider Benefits of Learning, Institute of Education, University of London. https://discovery.ucl.ac.uk/id/eprint/10015414/1/WBLResRep18.pdf

Spreen, O., & Strauss, E. (1991). *A compendium of neuropsychological tests: Administration, norms, and commentary*. Oxford University Press.

Srour, B., Fezeu, L. K., Kesse-Guyot, E., Allès, B., Méjean, C., Andrianasolo, R. M., Chazelas, E., Deschasaux, M., Hercberg, S., Galan, P., Monteiro, C. A., Julia, C., & Touvier, M. (2019). Ultra-processed food intake and risk of cardiovascular disease: Prospective cohort study (NutriNet-Santé). *British Medical Journal, 365,* l1451. https://doi.org/10.1136/bmj.l1451

Strauss, E., Sherman, E. M., & Spreen, O. (2006). *A compendium of neuropsychological tests: Administration, norms, and commentary*. Oxford University Press.

Sung, H., Park, J. M., Oh, S. U., Ha, K., & Joung, H. (2021). Consumption of ultra-processed foods increases the likelihood of having obesity in Korean women. *Nutrients, 13*(2), 698. https://doi.org/10.3390/nu13020698

Suter, W.N. (2012). *Introduction to educational research: A critical thinking approach*. (2nd ed.). Sage Publications.

Taha, H., Sawaed, S., & Jabareen-Taha, S. (2022). Are reading difficulties associated with poor verbal learning skills? Evidence from the fast-mapping paradigm. *Theory and Practice in Language Studies*, *12*(3), 431–436.

Tang, X., Zhao, W., Lu, M., Zhang, X., Zhang, P., Xin, Z., Sun, R., Tian, W., Cardoso, M. A., Yang, J. Simó, R., Zhou, J., & Stehouwer, C. D. (2021). Relationship between central obesity and the incidence of cognitive impairment and dementia from cohort studies involving 5,060,687 participants. *Neuroscience & Biobehavioral Reviews*, *130*, 301–313. https://doi.org/10.1016/j.neubiorev.2021.0 8.028

Tangney, C. C., Li, H., Wang, Y., Barnes, L., Schneider, J. A., Bennett, D. A., & Morris, M. C. (2014). Relation of DASH-and Mediterranean-like dietary patterns to cognitive decline in

older persons. *Neurology*, *83*(16), 1410–1416. https://doi.org/10.1212/WNL.0000000000000884

Taormina, R. J., & Gao, J. H. (2013). Maslow and the motivation hierarchy: Measuring satisfaction of the needs. *The American Journal of Psychology*, *126*(2), 155–177. https://doi.org/10.5406/amerjpsyc.126.2.0155

Tapsell, L. C., Neale, E. P., Satija, A., & Hu, F. B. (2016). Foods, nutrients, and dietary patterns: Interconnections and implications for dietary guidelines. *Advances in Nutrition*, *7*(3), 445–454. https://doi.org/10.3945/an.115.011718

The Nutrition Source. (2021). *Processed foods and health*. Harvard T.H. Chan School of Public Health. https://www.hsph.harvard.edu/nutritionsource/processed-foods/

Theobald, H. E. (2004). Whole diet approach to healthy eating. *Nutrition Bulletin*. *29*(1):44–49. https://doi.org/10.1111/j.1467-3010.2003.00389.x

Thomas, I. (2022). WISC-IV and Rey Auditory Verbal Learning Test indicators of specific learning disorder and discrepant academic achievement. *Journal of Psychoeducational Assessment*, *40*(8), 950–967.

Thurstone, L. L. (1938). *Primary mental abilities* (Vol. 119). University of Chicago Press.

Tombaugh, T. N., Kozak, J., & Rees, L. (1999). Normative data stratified by age and education for two measures of verbal fluency: FAS and animal naming. *Archives of Clinical Neuropsychology*, *14*(2), 167–177. https://doi.org/10.1016/S0887-6177(97)00095-4

Torres, S. J., Lautenschlager, N. T., Wattanapenpaiboon, N., Greenop, K. R., Beer, C., Flicker, L., Alfonso, H., & Nowson, C. A. (2012). Dietary patterns are associated with cognition among older people with mild cognitive impairment. *Nutrients*, *4*(11), 1542–1551. https://doi.org/10.3390/nu4111542

Tshisikhawe, M. P. (2017). *Challenges in implementing the National School Nutrition Programme for achieving educational objectives: a case study of schools in Vhembe District, Limpopo, South Africa* [Doctoral dissertation, University of Venda]. https://univendspace.univen.ac.za/handle/11602/877

Tulving, E., & Madigan, S. A. (1970). Memory and verbal learning. *Annual Review of Psychology*, *21*(1), 437–484. https://doi.org/10.1146/annurev.ps.21.020170.002253

United States Department of Agriculture & United States Department of Health and Human Services. (2020). *Dietary guidelines for Americans, 2020–2025* (USDA Publication No. USDA-FNS-2020-2025-DGA). https://www.dietaryguidelines.gov/

United States Department of Agriculture Agricultural Marketing Service. (2022). *Country of Origin Labeling (COOL) frequently asked questions*. https://www.ams.usda.gov/sites/default/files/media/FAQs%20for%20Consumers%20-%20English.pdf

Uribarri, J., Woodruff, S., Goodman, S., Cai, W., Chen, X. U. E., Pyzik, R., Yong, A., Striker, G. E., & Vlassara, H. (2010). Advanced glycation end products in foods and a practical guide to their reduction in the diet. *Journal of the American Dietetic Association*, *110*(6), 911–916. https://doi.org/10.1016/j.jada.2010.03.018

Valladares, M., Durán, E., Matheus, A., Durán-Agüero, S., Obregón, A. M., & Ramírez-Tagle, R. (2016). Association between eating behavior and academic performance in university students. *Journal of the American College of Nutrition*, *35*(8), 699–703. https://doi.org/10.1080/07315724.2016.1157526

Valls-Pedret, C., Sala-Vila, A., Serra-Mir, M., Corella, D., De la Torre, R., Martínez-González, M. Á., Martínez-Lapiscina, E. H., Fitó, M., Pérez-Heras, A., Salas-Salvadó, J., Estruch, R., & Ros, E. (2015). Mediterranean diet and age-related cognitive decline: A

randomized clinical trial. *JAMA Internal Medicine*, *175*(7), 1094–1103. https://doi.org/10.1001/jamainternmed.2015.1668

Van den Brink, A. C., Brouwer-Brolsma, E. M., Berendsen, A. A., & van de Rest, O. (2019). The Mediterranean, Dietary Approaches to Stop Hypertension (DASH), and Mediterranean-DASH Intervention for Neurodegenerative Delay (MIND) diets are associated with less cognitive decline and a lower risk of Alzheimer's disease—A review. *Advances in Nutrition*, *10*(6), 1040–1065. https://doi.org/10.1093/advances/nmz054

Van Lenthe, F. J., Jansen, T., & Kamphuis, C. B. (2015). Understanding socio-economic inequalities in food choice behaviour: can Maslow's pyramid help?. *British Journal of Nutrition*, *113*(7), 1139–1147. https://doi.org/10.1017/S0007114515000288

Verger, P., Combes, J. B., Kovess-Masfety, V., Choquet, M., Guagliardo, V., Rouillon, F., & Peretti-Wattel, P. (2009). Psychological distress in first year university students: socioeconomic and academic stressors, mastery and social support in young men and women. *Social Psychiatry and Psychiatric Epidemiology*, *44*(8), 643–650. https://doi.org/10.1007/s00127-008-0486-y

Walker, A. D. M. (2020). *Perceptions of Nutrition and Academic Performance in College Freshmen: A Phenomenological Qualitative Study* [Doctoral dissertation, Texas A&M University]. Education Commons. https://digitalcommons.tamuc.edu/etd/343

Wang, L., Steele, E. M., Du, M., Pomeranz, J. L., O'Connor, L. E., Herrick, K. A., Luo, H., Zhang, X., Mozaffarian, D., & Zhang, F. F. (2021). Trends in consumption of ultraprocessed foods among US youths aged 2-19 years, 1999-2018. *JAMA*, *326*(6), 519–530. https://doi.org/10.1001/jama.2021.10238

Wang, Y., & Black, M. (2019, June 13). Child Food Insecurity and Neighborhood Food Environment in Relation to Academic Performance and Behavior Problems Among a

National Sample of Kindergarten Children (OR02-04-19). *Current Developments in Nutrition*, *3*(Supplement_1), 133. https://doi.org/10.1093/cdn/nzz051.OR02-04-19

Watts, A. W., Valente, M., Tu, A., & Mâsse, L. C. (2017). Eating away from home: Influences on the dietary quality of adolescents with overweight or obesity. *Canadian Journal of Dietetic Practice and Research*, *78*(4), 166–171. https://doi.org/10.3148/cjdpr-2017-010

Weaver, C. M., Dwyer, J., Fulgoni III, V. L., King, J. C., Leveille, G. A., MacDonald, R. S., Ordovas, J., & Schnakenberg, D. (2014). Processed foods: Contributions to nutrition. *The American Journal of Clinical Nutrition*, *99*(6), 1525–1542. https://doi.org/10.3945/ajcn.114.089284

Weinstein, G., Vered, S., Ivancovsky-Wajcman, D., Ravona-Springer, R., Heymann, A., Zelber-Sagi, S., Shahar, D. R., & Beeri, M. S. (2023). Consumption of ultra-processed food and cognitive decline among older adults with type-2 diabetes. *The Journals of Gerontology: Series A*, *78*(1), 1–9. https://doi.org/10.1093/gerona/glac070

Wen, X., Kong, K. L., Eiden, R. D., Sharma, N. N., & Xie, C. (2014). Sociodemographic differences and infant dietary patterns. *Pediatrics*, *134*(5), 1387–1398. https://doi.org/10.1542/peds.2014-1045

West, R. K., Moshier, E., Lubitz, I., Schmeidler, J., Godbold, J., Cai, W., Uribarri, J., Vlassara, H., Silverman, J. M., & Beeri, M. S. (2014). Dietary advanced glycation end products are associated with decline in memory in young elderly. *Mechanisms of Ageing and Development*, *140*, 10–12. https://doi.org/10.1016/j.mad.2014.07.001

Whatnall, M., Clarke, E., Collins, C. E., Pursey, K., & Burrows, T. (2022). Ultra-processed food intakes associated with 'food addiction'in young adults. *Appetite*, *178*, 106260. https://doi.org/10.1016/j.appet.2022.106260

Whiteside, D. M., Kealey, T., Semla, M., Luu, H., Rice, L., Basso, M. R., & Roper, B. (2016). Verbal fluency: Language or executive function measure? *Applied Neuropsychology: Adult*, *23*(1), 29–34. https://doi.org/10.1080/23279095.2015.1004574

Whyte, A. R., & Williams, C. M. (2015). Effects of a single dose of a flavonoid-rich blueberry drink on memory in 8 to 10 y old children. *Nutrition*, *31*(3), 531–534. https://doi.org/10.1016/j.nut.2014.09.013

Więckowska-Gacek, A., Mietelska-Porowska, A., Wydrych, M., & Wojda, U. (2021). Western diet as a trigger of Alzheimer's disease: From metabolic syndrome and systemic inflammation to neuroinflammation and neurodegeneration. *Ageing Research Reviews*, *70*, 101397. https://doi.org/10.1016/j.arr.2021.101397

Willis, D. E. (2021). Feeding inequality: Food insecurity, social status and college student health. *Sociology of Health & Illness*, *43*(1), 220–237. https://doi.org/10.1111/1467-9566.13212

Wilson, B. A., Watson, P. C., Baddeley, A. D., Emslie, H. A. Z. E. L., & Evans, J. J. (2000). Improvement or simply practice? The effects of twenty repeated assessments on people with and without brain injury. *Journal of the International Neuropsychological Society*, *6*(4), 469–479. https://doi.org/10.1017/s1355617700644053

Wilson, M. M., Reedy, J., & Krebs-Smith, S. M. (2016). American diet quality: where it is, where it is heading, and what it could be. *Journal of the Academy of Nutrition and Dietetics*, *116*(2), 302–310. https://doi.org/10.1016/j.jand.2015.09.020

Winpenny, E. M., van Sluijs, E. M., White, M., Klepp, K. I., Wold, B., & Lien, N. (2018). Changes in diet through adolescence and early adulthood: Longitudinal trajectories and association with key life transitions. *International Journal of Behavioral Nutrition and Physical Activity*, *15*(1), 1–9. https://doi.org/10.1186/s12966-018-0719-8

World Health Organization. (2019*). Risk reduction of cognitive decline and dementia: WHO guidelines*. https://www.who.int/publications/i/item/9789241550543

Wu, J. H., Trieu, K., Coyle, D., Huang, L., Wijesuriya, N., Nallaiah, K., Lung, T., Di Tanna, G. L., Zheng, M., Mozaffarian, D., MacMillan, F., Simmons, D., Wu, T., Twigg, S., Gauld, A., Constantino, M., McGill, M., & Neal, B. (2022). Testing the Feasibility and Dietary Impact of a "Produce Prescription" Program for Adults with Undermanaged Type 2 Diabetes and Food Insecurity in Australia. *The Journal of Nutrition*, *152*(11), 2409–2418. https://doi.org/10.1093/jn/nxac152

Yaffe, K., Lindquist, K., Schwartz, A. V., Vitartas, C., Vittinghoff, E., Satterfield, S., Simonsick, E. M., Launer, L., Rosano, C., Cauley, J. A. & Harris, T. (2011). Advanced glycation end product level, diabetes, and accelerated cognitive aging. *Neurology*, *77*(14), 1351–1356. https://doi.org/10.1212/WNL.0b013e3182315a56

Yang, Q., Zhang, Z., Steele, E. M., Moore, L. V., & Jackson, S. L. (2020). Ultra-processed foods and excess heart age among US adults. *American Journal of Preventive Medicine*, *59*(5), e197–e206. https://doi.org/10.1016/j.amepre.2020.06.013

Zeraatkar, D., Han, M. A., Guyatt, G. H., Vernooij, R. W., El Dib, R., Cheung, K., Milio, K., Zworth, M., Bartoszko, J. J., Valli, C., Rabassa, M., Lee, Y., Zajac, J., Prokop-Dorner, A., Lo, C., Bala, M. M., Alonso-Coello, P., Hannah, S. E., & Johnston, B. C. (2019). Red and processed meat consumption and risk for all-cause mortality and cardiometabolic outcomes: A systematic review and meta-analysis of cohort studies. *Annals of Internal Medicine*, *171*(10), 703–710. https://doi.org/10.7326/M19-0655

Zhang, Y., Huang, M., Zhuang, P., Jiao, J., Chen, X., Wang, J., & Wu, Y. (2018). Exposure to acrylamide and the risk of cardiovascular diseases in the National Health and Nutrition

Examination Survey 2003–2006. *Environment International*, *117*, 154–163. https://doi.org/10.1016/j.envint.2018.04.047

Zhang, Z., Jackson, S. L., Martinez, E., Gillespie, C., & Yang, Q. (2021). Association between ultraprocessed food intake and cardiovascular health in US adults: A cross-sectional analysis of the NHANES 2011–2016. *The American Journal of Clinical Nutrition*, *113*(2), 428–436. https://doi.org/10.1093/ajcn/nqaa276

Zinöcker, M. K., & Lindseth, I. A. (2018). The Western diet–microbiome-host interaction and its role in metabolic disease. *Nutrients*, *10*(3), 365. https://doi.org/10.3390/nu10030365

Appendix A: Letter to Participants

Dear Participant,

Greetings!

You are being invited to participate in a study I am conducting about the effect of breakfast on learning. This study is for a dissertation I am writing to complete my Ed.D. in Educational Leadership at Wilkes University. Your time and assistance would be greatly appreciated!

In order to proceed and complete this study, you must be at least 18 years of age. Specific criteria for inclusion include: (1) age 18-25, (2) college status, and (2) willingness and ability to consume the foods selected, which may include a combination of crackers, jam, juice, orange segments, and toaster pastries. To avoid additional complications and minimize variability in data, additional exclusion criteria include: known food allergies or sensitivities, celiac disease, pregnancy, lactose intolerance, low-calorie and/or low-sodium diets, and diagnosis and/or treatment of cardiovascular events, diabetes mellitus, dyslipidemia, and hypertension. The specific hypothesis being tested will be shared once all data collection is complete.

The study would involve eating the breakfast provided and answering questions on an online quiz platform. For a period of two hours, you would be encouraged to remain seated and rest, watch something for entertainment, do schoolwork, or do other non-strenuous activities. This waiting period also involves learning tests that add up to approximately 35 minutes. You may freely use the restroom and drink as much water as you wish. This process will be repeated one week later. Results will be stored and reported confidentially. Should you have any questions, wish to withdraw at any time, or are interested in learning more about this study, please contact me at 740-804-2143. If you choose not to participate, simply delete this email and you will not be contacted again.

If you fit the criteria for participation in this study, please acknowledge this below and you will be provided more information.

Thank you for your time! Your willingness to share your experiences for this study is greatly appreciated.

All the best,

William Swinsburg

If you fit the requirements listed above and desire to participate in this study, please reply to this email indicating:

______Yes, I fit the requirements for this study and am interested in participating.

The researcher may contact me at the following email address: ________________________

Appendix B: Sample Informed Consent
Wilkes University
School of Education
84 W. South Street Wilkes-Barre, PA 18766

Statement of Informed Consent

Agreement to Participate

Title of Study: The Impact of Breakfast on Learning: A Randomized Crossover Trial
Principal Investigator: William A. Swinsburg
Phone: (740) 804-2143
Email: william.swinsburg@wilkes.edu

You are invited to participate in a research study organized by William Swinsburg as part of the requirements to earn the Doctor of Education degree in Educational Leadership from Wilkes University. Please read the information below and contact me if you have questions or concerns. Your participation in this study is completely voluntary and there will be no negative consequences if you choose not to participate. You may stop participating at any time without penalty or losing benefits. However, your participation is important to the success of this study, and I am thankful for your help.

Background and Purpose of the Study: The purpose of this study is to examine how breakfast affects learning. The specific hypothesis being tested will be shared once all data collection is complete. This study involves a learning test housed on Flexiquiz, a website designed to allow teachers to house quiz questions in a safe online environment.

Participant Expectations: As a part of this experiment, you will eat a breakfast (which may include a combination of: crackers, jam, juice, orange segments, and toaster pastries). A combined list of potential ingredients can be found here. For the next two hours, you are encouraged to remain seated and rest, watch something for entertainment, do schoolwork, or do other non-strenuous activities. This waiting period will also involve learning tests that add up to approximately 35 minutes. You may freely use the restroom and drink as much water as you wish. This process will be repeated one week later. Your name and email will be kept so that I can share more information at a later time, but the data will be stored and reported confidentially. Clicking on the "Next Page" button at the start of the quiz will begin the study. Once you have completed all quiz activities on the second day of the study, you are finished. Nothing further will be required of you.

Benefits and Risks: Compensation for participating in this study includes two breakfasts given at the start of each day of the study, as well as a $5 Amazon gift card given at the completion of the study. Another benefit is time to rest and do schoolwork or other non-strenuous activities. Other benefits include experiencing the effect of breakfast on learning and the knowledge that you have helped in scholarly research. The results of this study will add to the research on breakfast and learning. Currently, there is a gap in knowledge regarding how different types of food affect learning. The results of this study may help to inform recommendations and other policies. Other possible benefits include positive changes in health or well-being as a result of increased awareness of the potential connection between breakfast and learning.

The primary risk is a food allergy or sensitivity. Therefore, if you have a known food allergy or sensitivity, you may not participate in this study. If needed, university procedures will be followed to notify on-campus healthcare professionals. You may experience discomfort due to not knowing all of the answers to quiz questions, but this discomfort is not expected to be more than the discomfort from any other assessment you may have taken. I will not know which answers belong to which participant, and there are no negative consequences for not knowing the answers.

Confidentiality Provisions: All responses will be collected and stored confidentially. Scores and results will be combined, and no identifiable information will be reported.

Contact Information: If you have questions or concerns about this research study, contact the principal investigator, William Swinsburg, at the number or email address above. You may also contact the faculty member supervising this research, Dr. Karim Medico, at (570) 408-5512 or karim.medico@wilkes.edu.

If you have questions or concerns, or if you feel your rights have been violated as a result of participating in this research, you may contact the chair of the Wilkes University Institutional Review Board (IRB) at (570) 408-5512.

Statement of Consent: By your completion of this quiz, and signing your name below, you are giving informed consent for the use of your responses in this research.

Signature ____ Date: ___________

Name (Print) ____ Username:_______

Appendix C: RAVLT Word Lists

Table C1

RAVLT Word Lists

Form	Source	Stimulus List (List A)	Interference list (List B)
1	Rey (1958)	Drum, curtain, bell, coffee, school, parent, moon, garden, hat, farmer, nose, turkey, color, house, river	Desk, ranger, bird, shoe, stove, mountain, glasses, towel, cloud, boat, lamb, gum, pencil, church, fish
2	Lezak (1983)	Book, flower, train, rug, meadow, harp, salt, finger, apple, chimney, button, log, key, rattle, gold	Bowl, dawn, judge, grant, insect, plane, county, pool, seed, sheep, meal, coat, bottle, peach, chair
3	Shapiro and Harrison (1990)	Street, grass, door, arm, star, wife, window, city, pupil, cabin, lake, pipe, skin, fire, clock	Baby, ocean, palace, lip, bar, dress, steam, coin, rock, army, building, friend, storm, village, cell
4	Shapiro and Harrison (1990)	Tower, wheat, queen, sugar, home, boy, doctor, camp, flag, letter, corn, nail, cattle, shore, body	Sky, dollar, valley, butter, hall, diamond, winter, mother, Christmas, meat, forest, gold, plant, money, hotel

Note. Rey Auditory-Verbal Learning Test (RAVLT) form numbers correspond to those detailed in Hawkins, et al. (2004).

Appendix D: Letters of Permission

Good morning _____________,

My name is William Swinsburg, and I am a doctoral candidate pursuing my Ed.D. in Educational Leadership at Wilkes University. For my dissertation, I am studying the effect of food processing level on verbal learning and fluency. I am writing to request your institution's participation in this study. I have summarized the nature of the study in the attached email to potential participants as well as the attached letter of informed consent. If desired, the full proposal is attached. If interested, I would ask that the attached email be sent to all of [University Name]'s students between 18-25 years of age.

I would be happy to answer any questions that may arise. Feel free to reply back to this address or call me directly at (740) 804-2143. Thank you for your time, and I look forward to collaborating with you and the students at [University Name].

Sincerely,

William Swinsburg

Appendix E: Additional Figures

Figure E1

Histogram of Verbal Learning Total Recall for Minimally Processed Meals at 30 Minutes

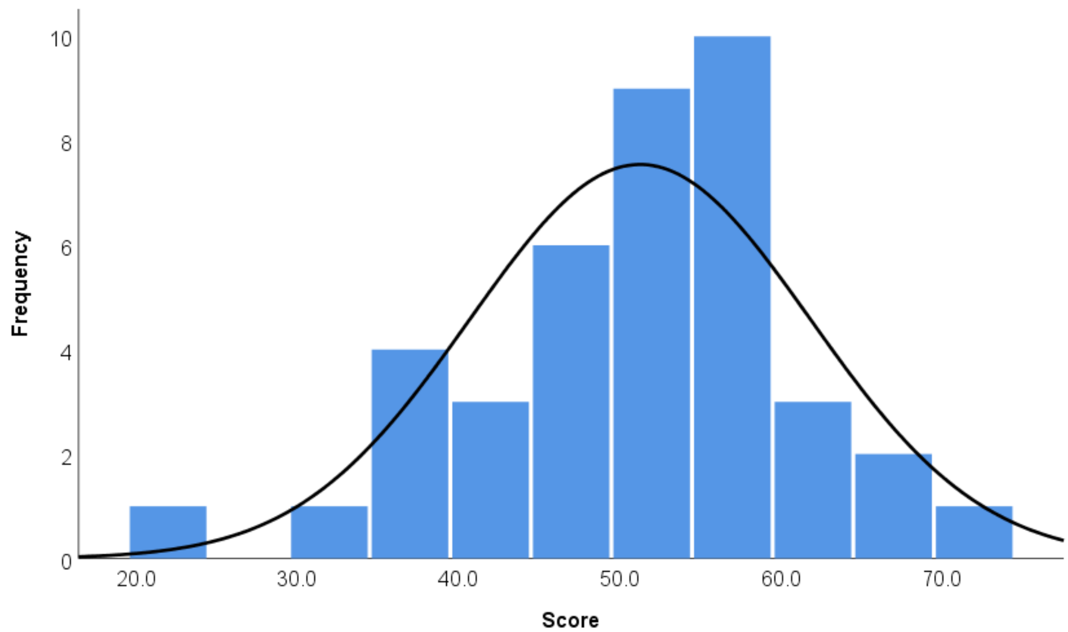


Figure E2

Histogram of Verbal Learning Total Recall for Minimally Processed Meals at 90 Minutes

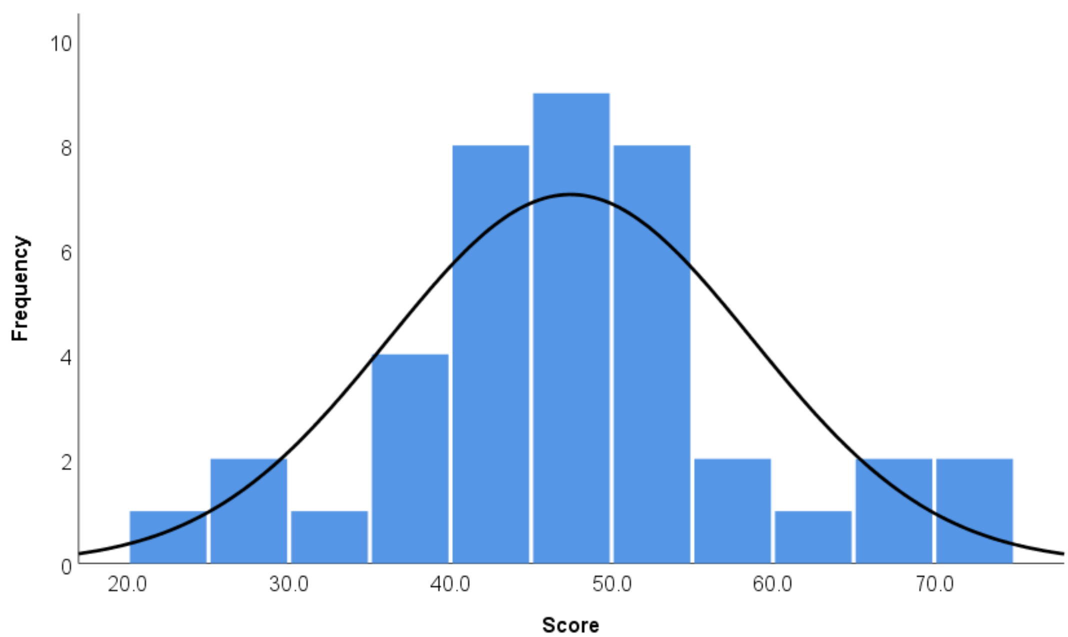


Figure E3

Histogram of Verbal Learning Total Recall for Ultra-Processed Meals at 30 Minutes

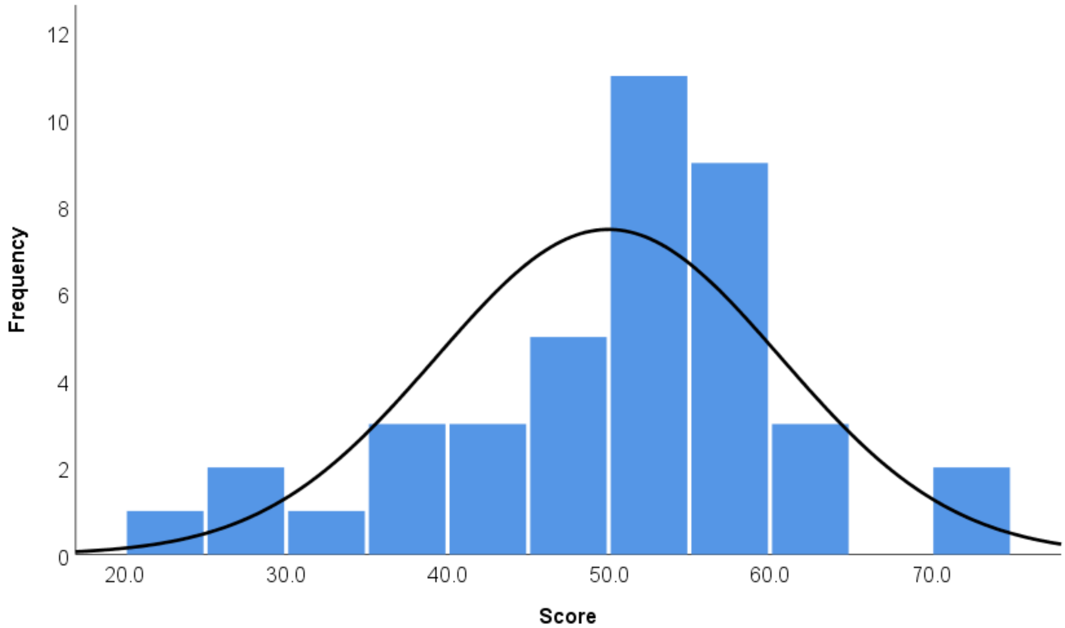


Figure E4

Histogram of Verbal Learning Total Recall for Ultra-Processed Meals at 90 Minutes

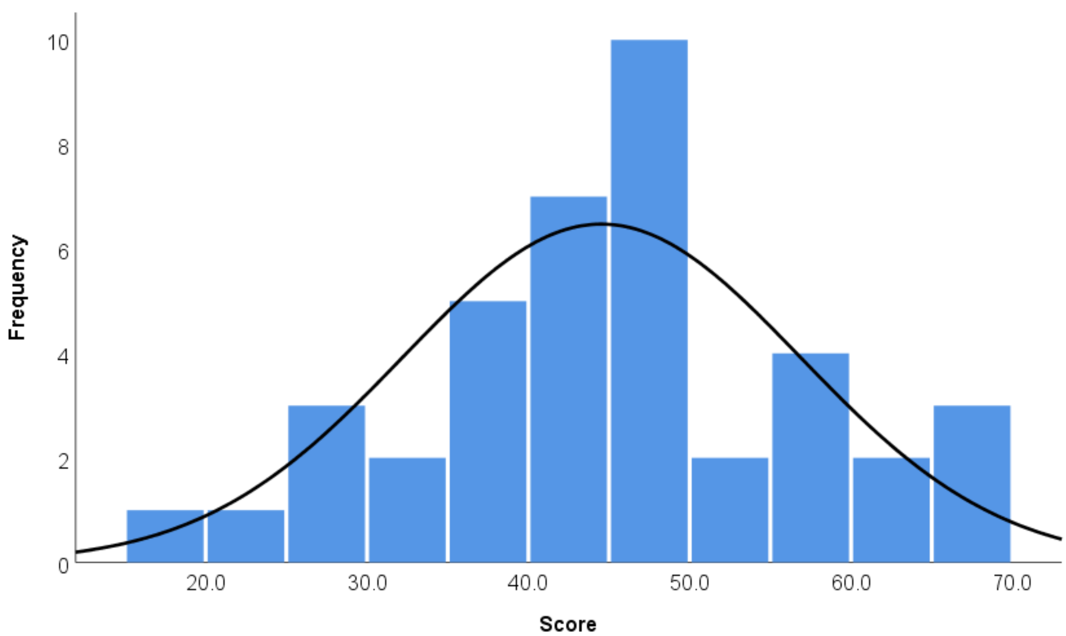


Figure E5

Histogram of Verbal Learning Immediate Memory for Minimally Processed Meals at 30 Minutes

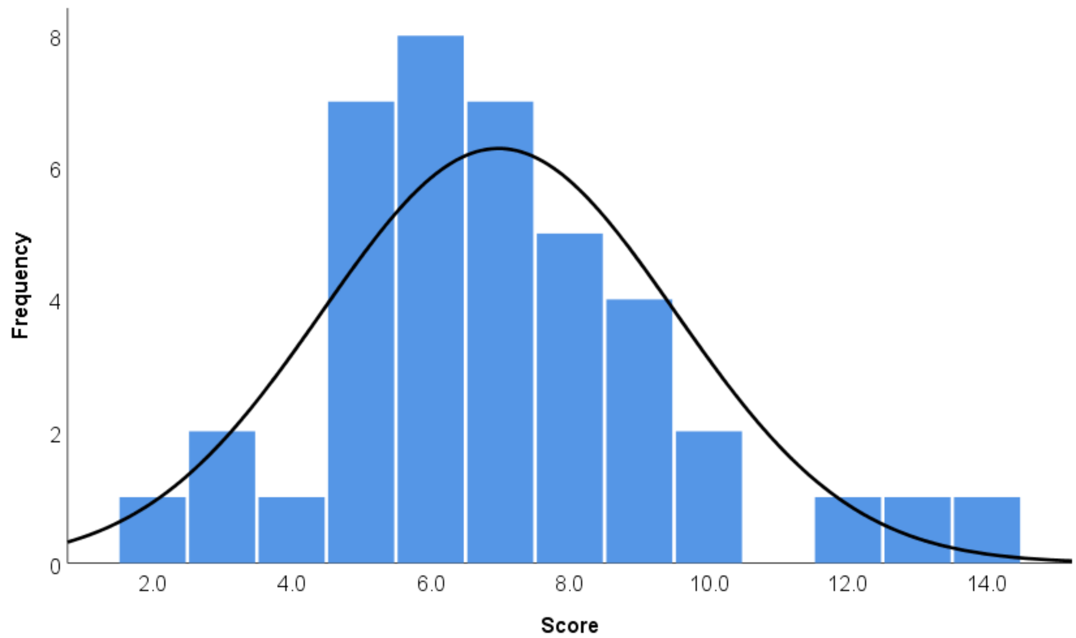


Figure E6

Histogram of Verbal Learning Immediate Memory for Minimally Processed Meals at 90 Minutes

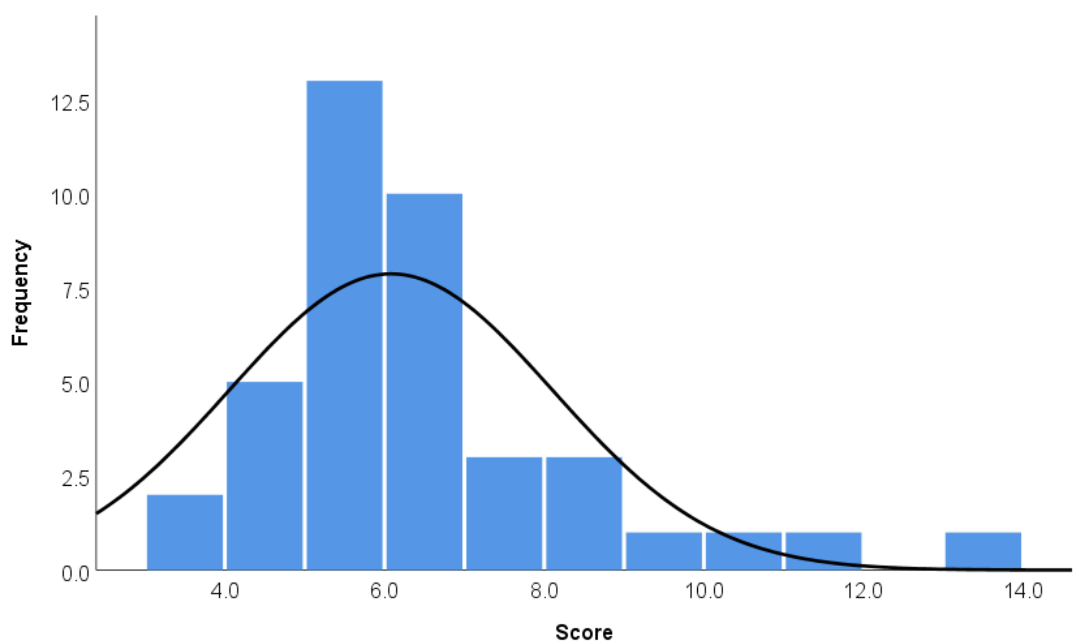


Figure E7

Histogram of Verbal Learning Immediate Memory for Ultra-Processed Meals at 30 Minutes

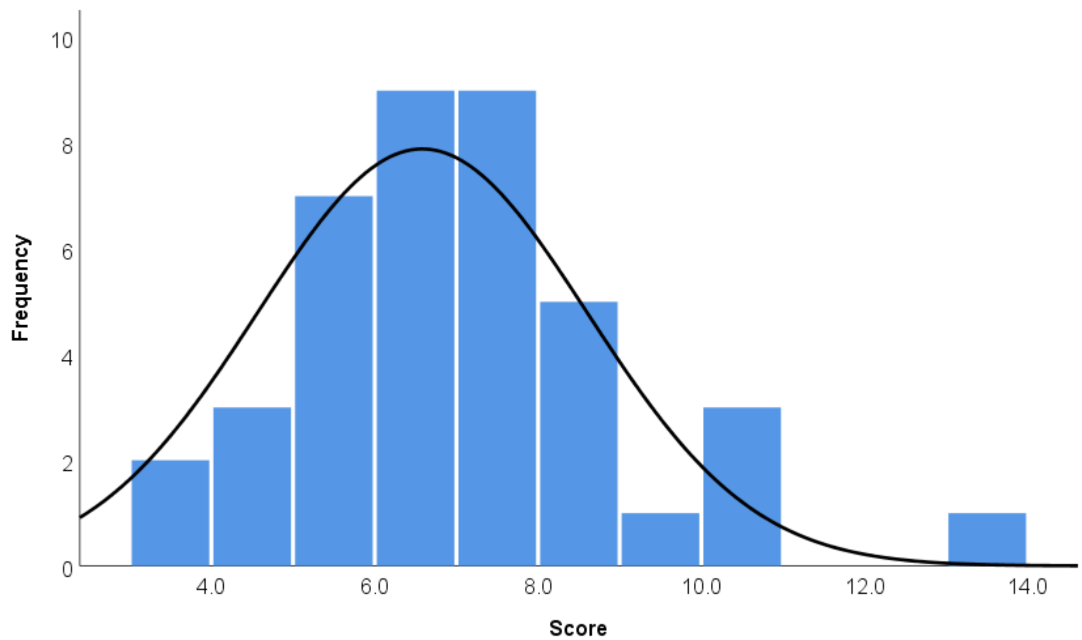


Figure E8

Histogram of Verbal Learning Immediate Memory for Ultra-Processed Meals at 90 Minutes

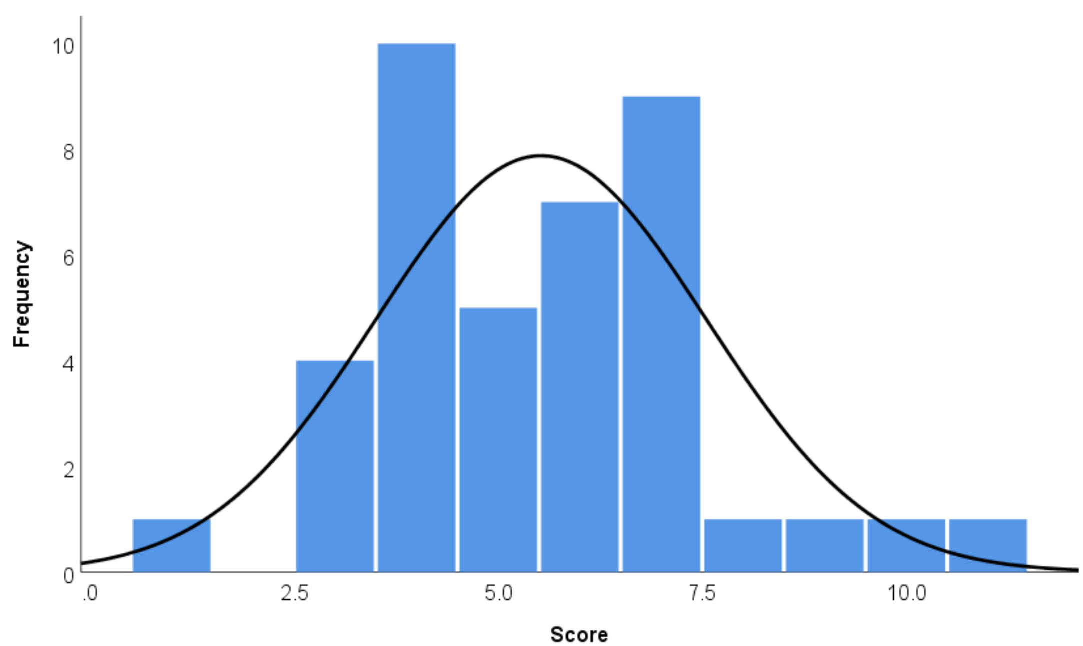


Figure E9

Histogram of Verbal Learning Delayed Recall for Minimally Processed Meals at 30 Minutes

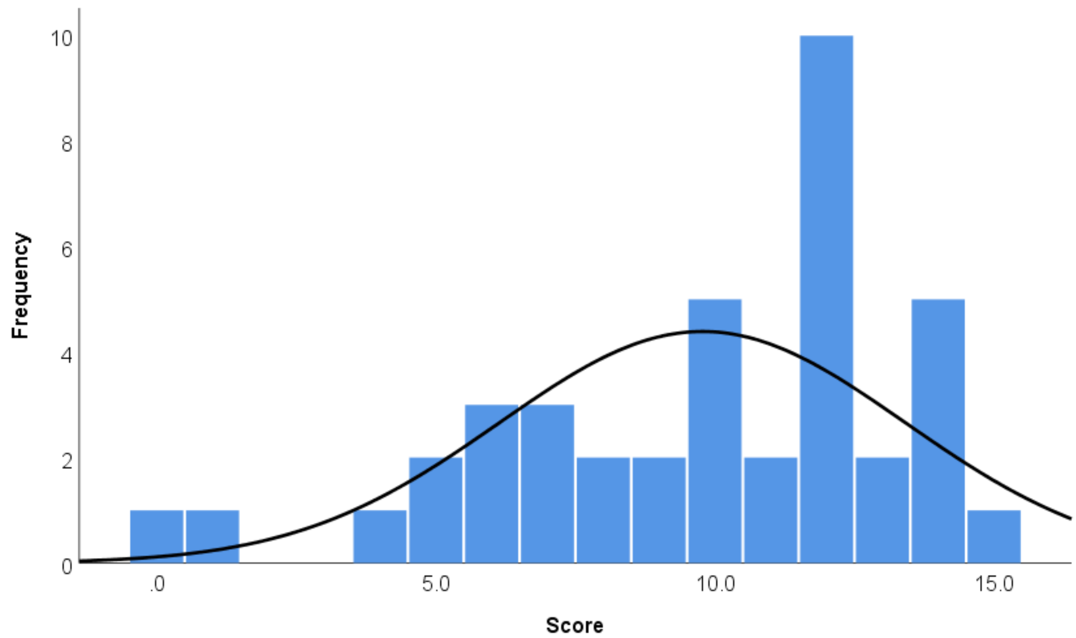


Figure E10

Histogram of Verbal Learning Delayed Recall for Minimally Processed Meals at 90 Minutes

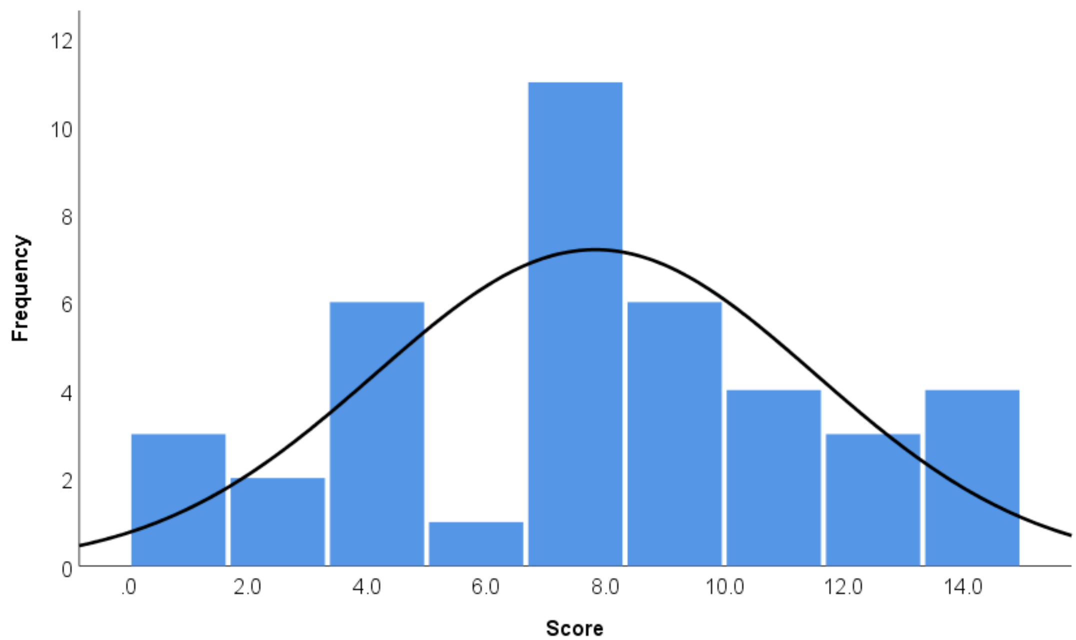


Figure E11

Histogram of Verbal Learning Delayed Recall for Ultra-Processed Meals at 30 Minutes

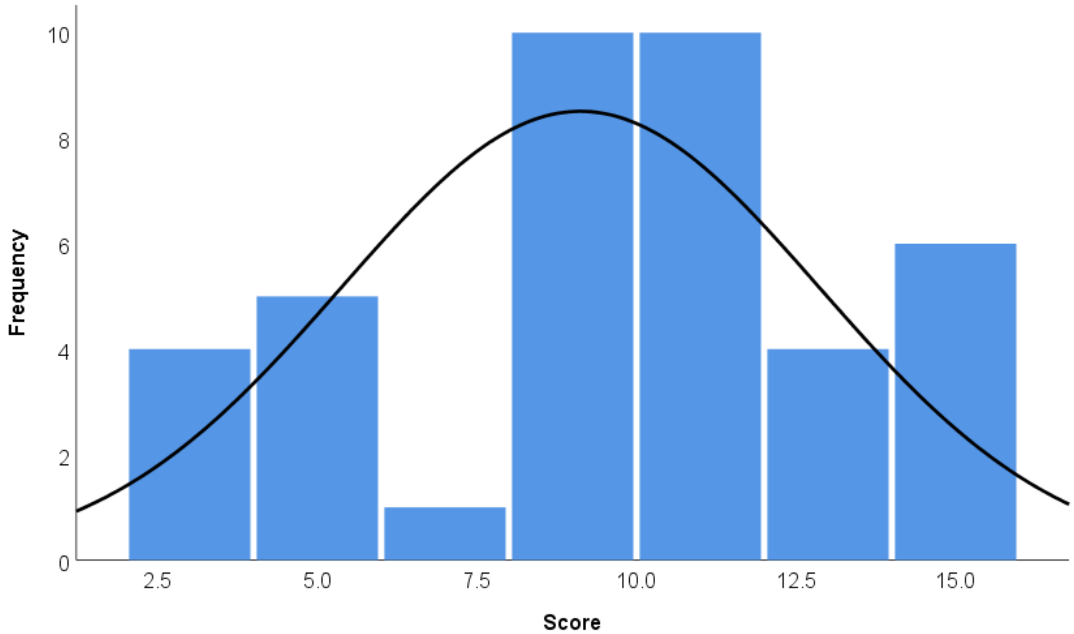


Figure E12

Histogram of Verbal Learning Delayed Recall for Ultra-Processed Meals at 90 Minutes

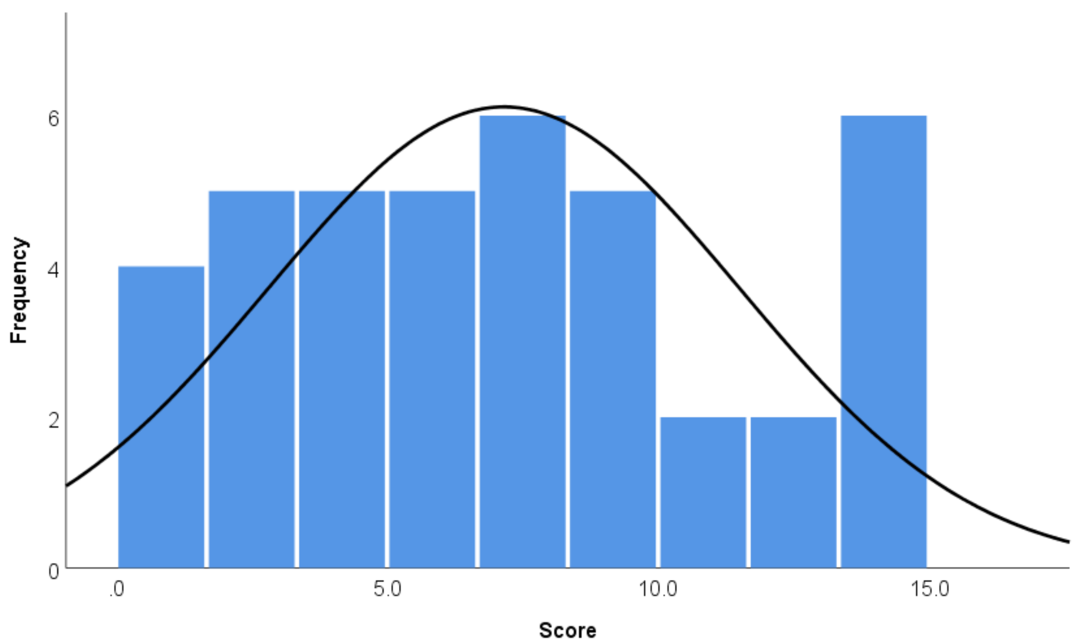


Figure E13

Histogram of Verbal Learning Recognition for Minimally Processed Meals at 30 Minutes

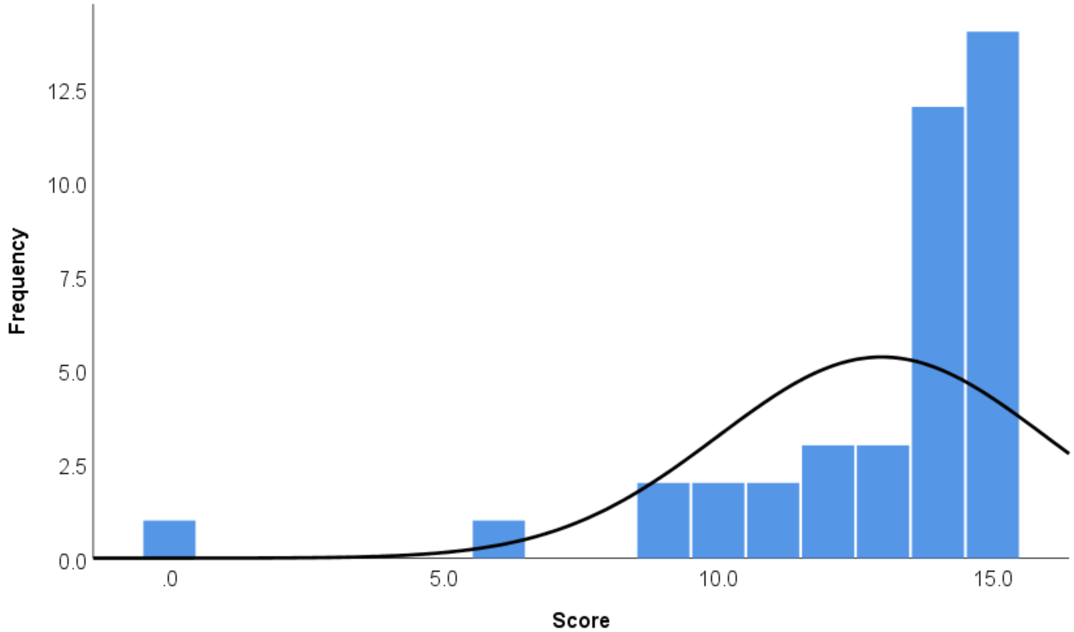


Figure E14

Histogram of Verbal Learning Recognition for Minimally Processed Meals at 90 Minutes

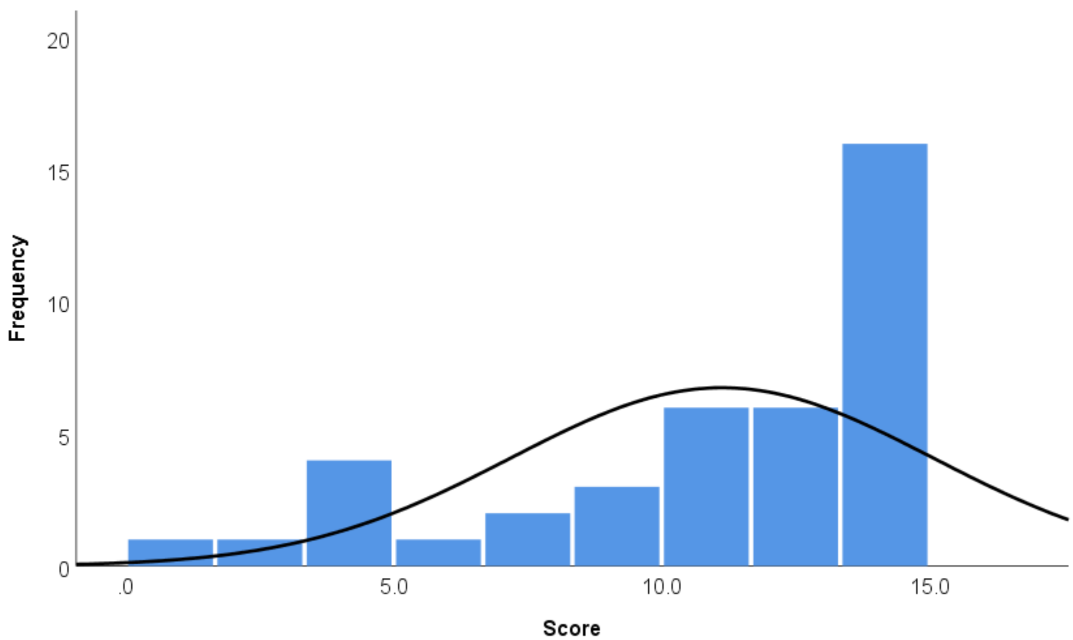


Figure E15

Histogram of Verbal Learning Recognition for Ultra-Processed Meals at 30 Minutes

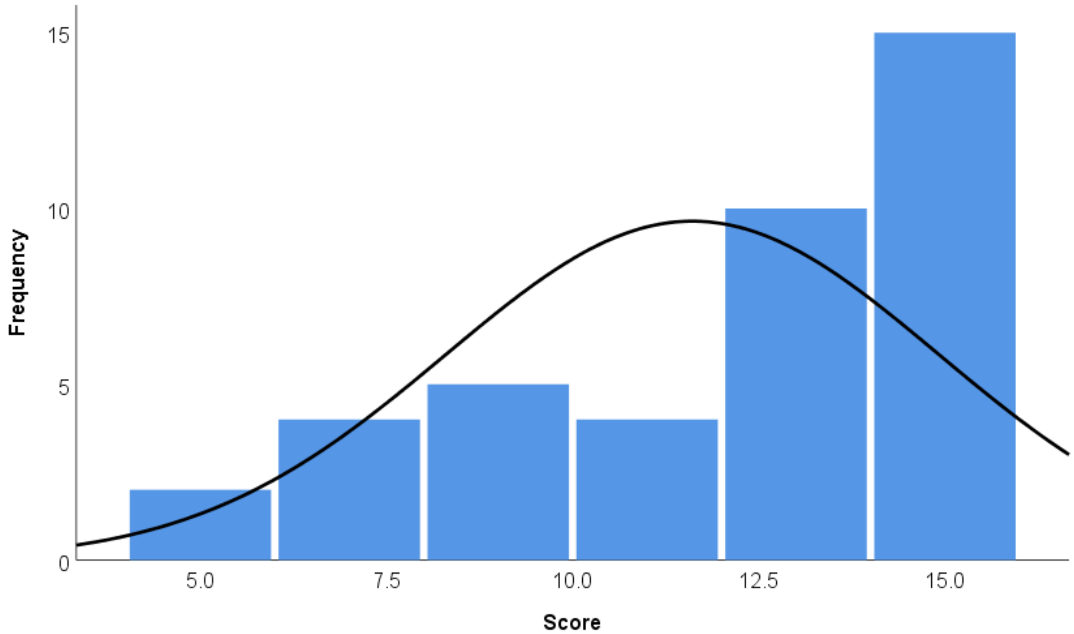


Figure E16

Histogram of Verbal Learning Recognition for Ultra-Processed Meals at 90 Minutes

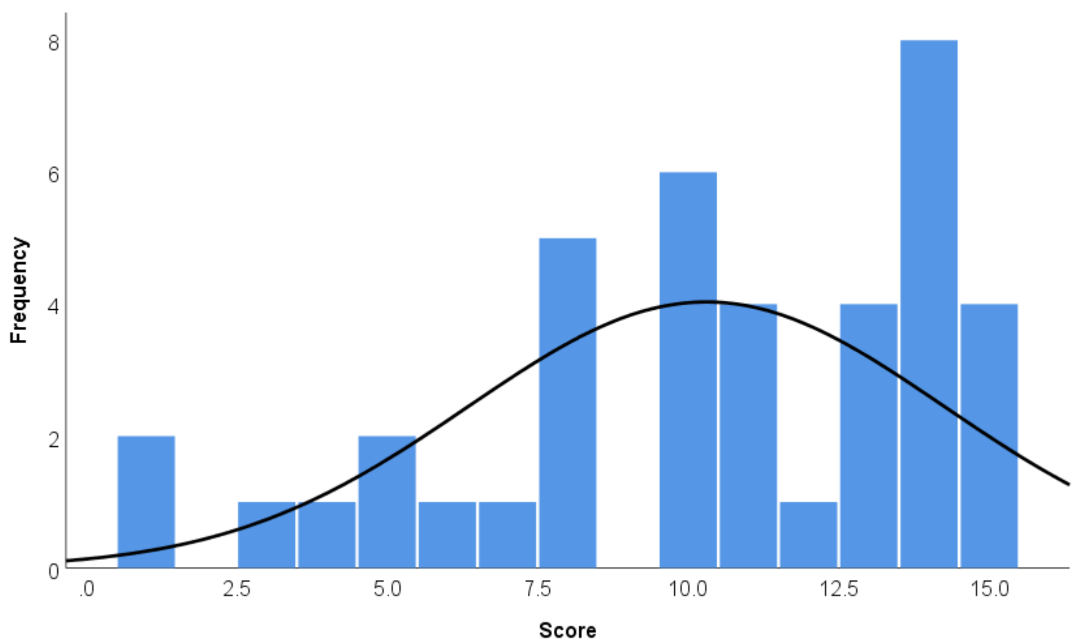


Figure E17

Histogram of Verbal Learning Interference List Score for Minimally Processed Meals at 30 Minutes

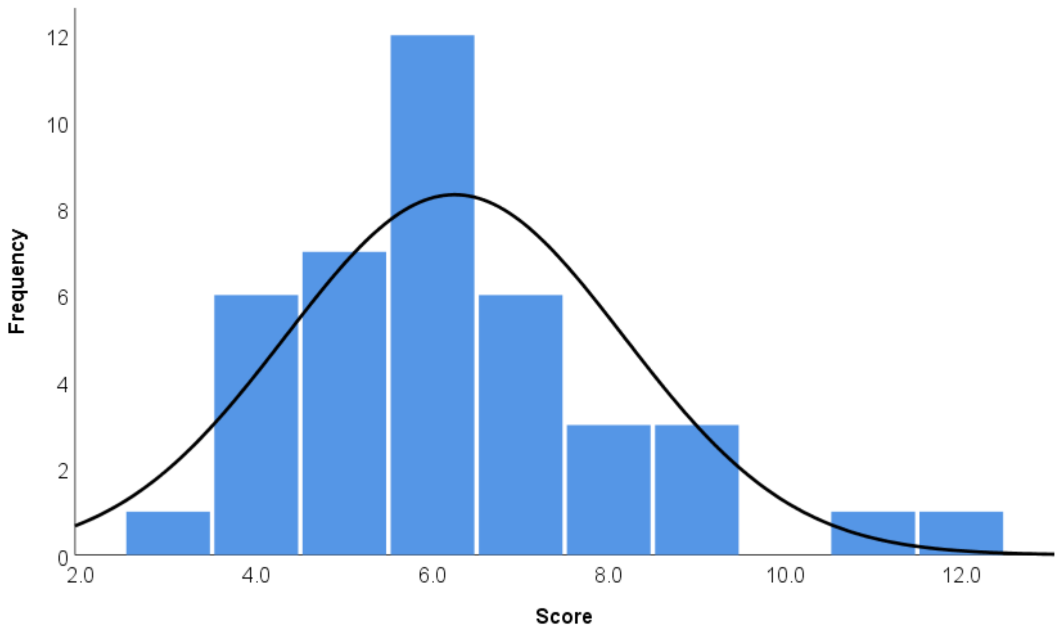


Figure E18

Histogram of Verbal Learning Interference List Score for Minimally Processed Meals at 90 Minutes

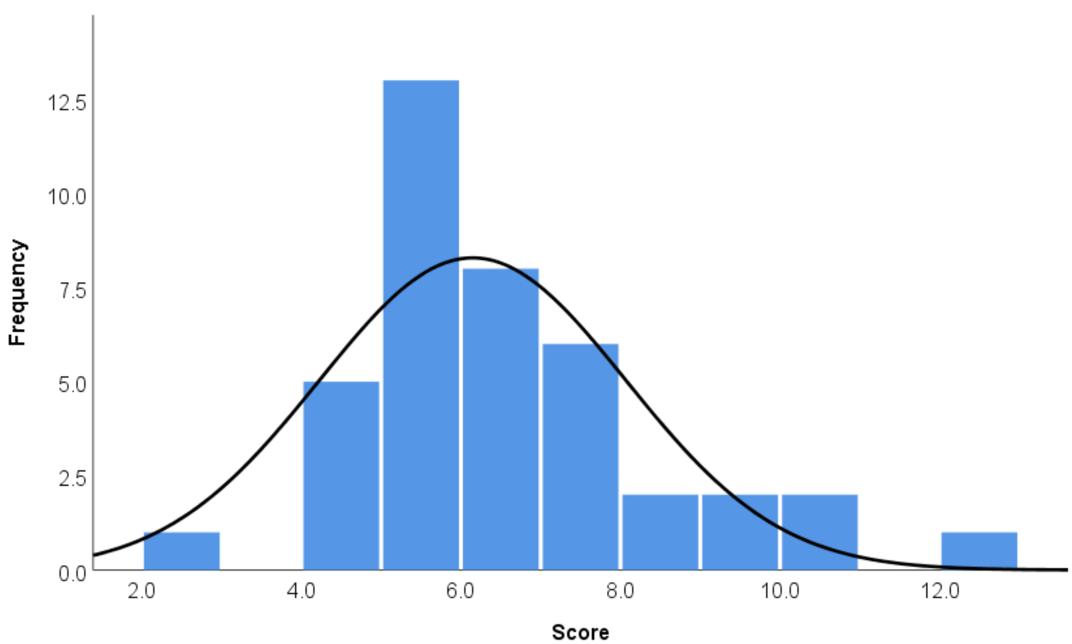


Figure E19

Histogram of Verbal Learning Interference List Score for Ultra-Processed Meals at 30 Minutes

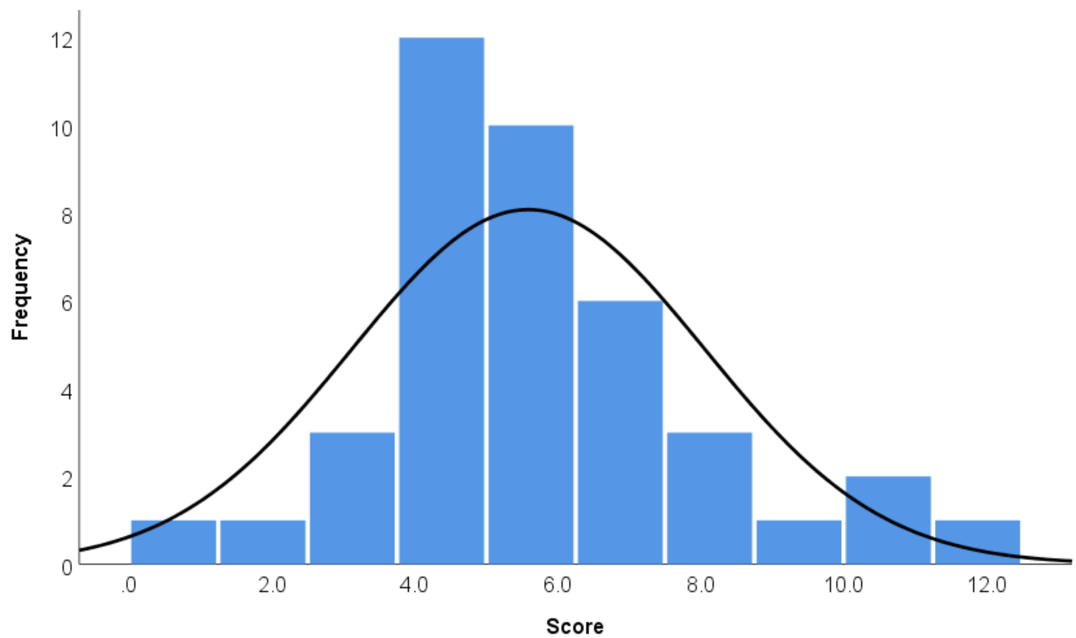


Figure E20

Histogram of Verbal Learning Interference List Score for Ultra-Processed Meals at 90 Minutes

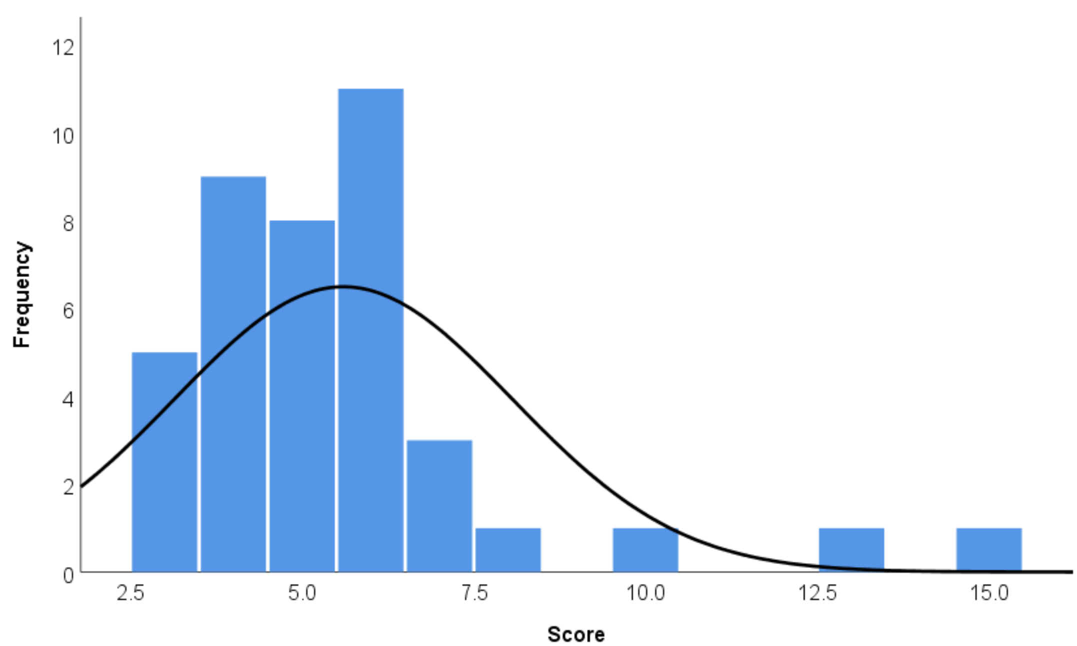


Figure E21

Histogram of Verbal Learning Retention for Minimally Processed Meals at 30 Minutes

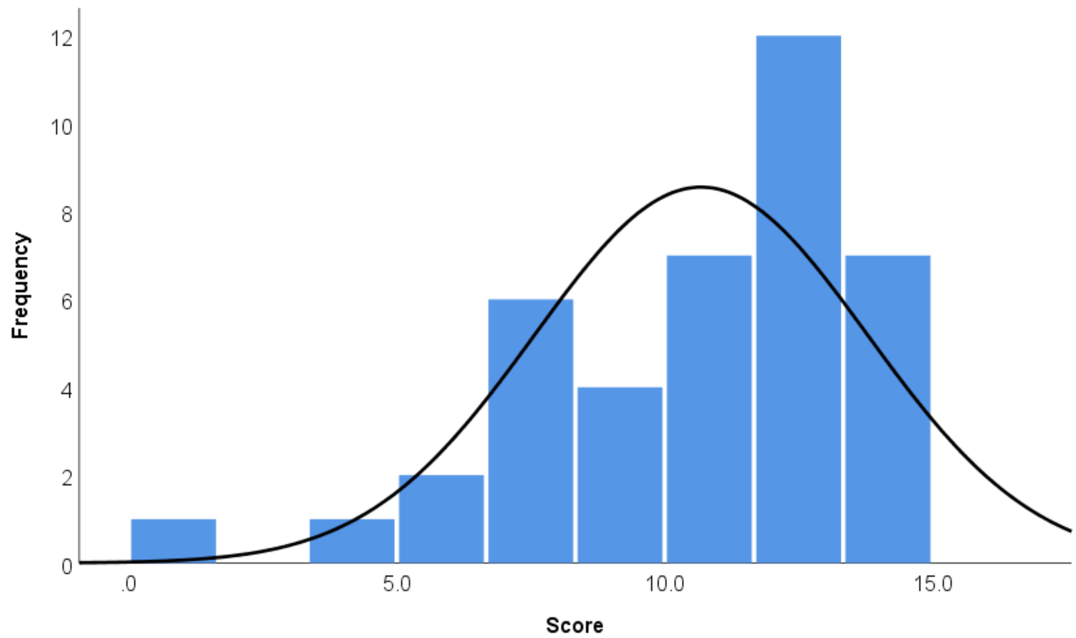


Figure E22

Histogram of Verbal Learning Retention for Minimally Processed Meals at 90 Minutes

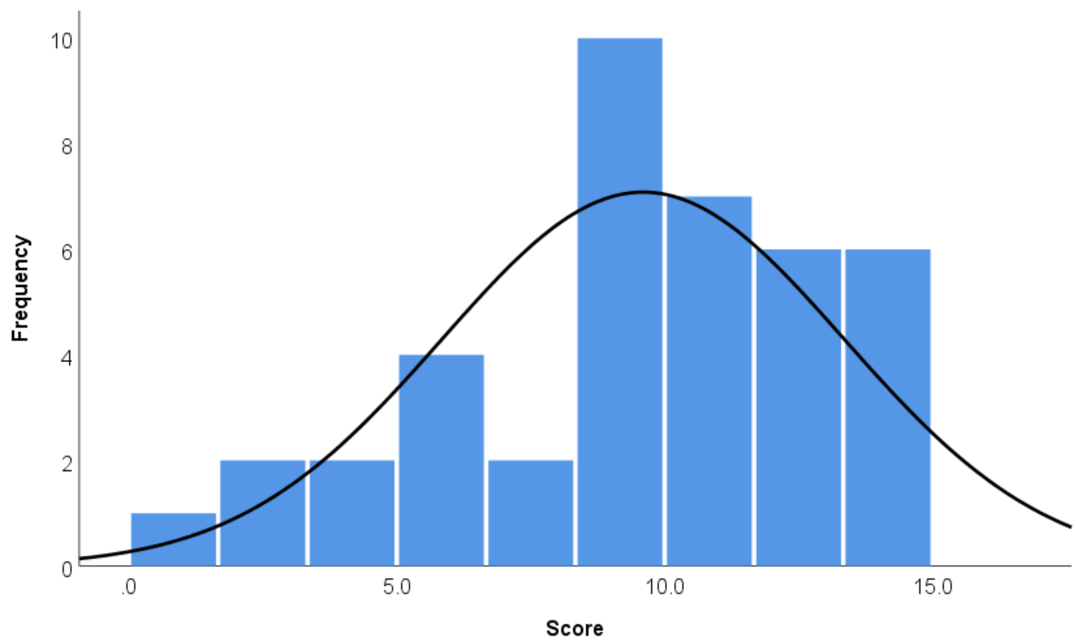


Figure E23

Histogram of Verbal Learning Retention for Ultra-Processed Meals at 30 Minutes

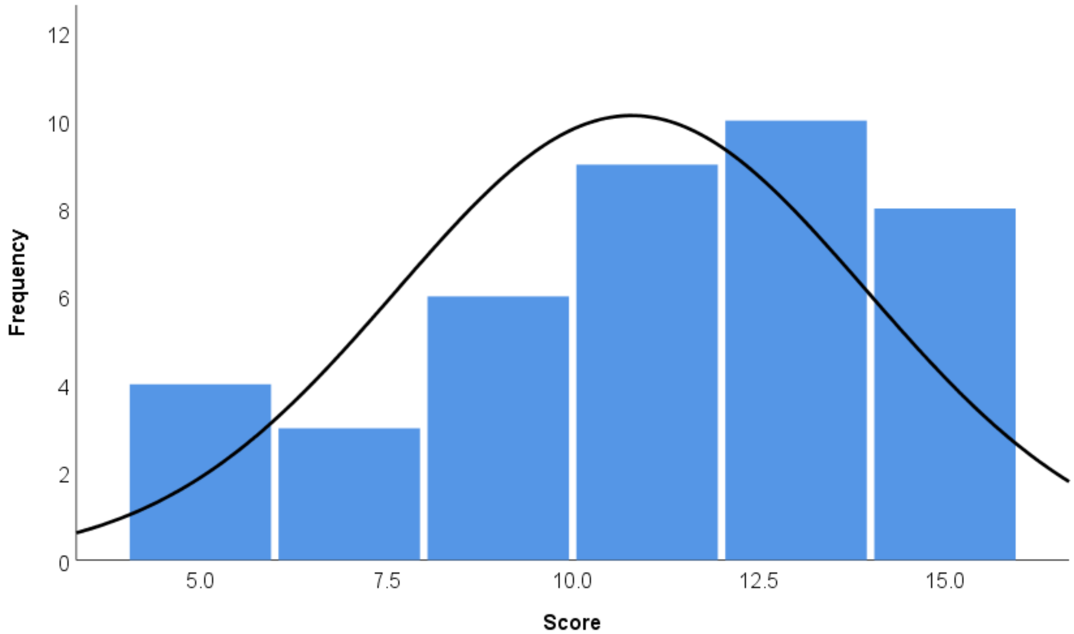


Figure E24

Histogram of Verbal Learning Retention for Ultra-Processed Meals at 90 Minutes

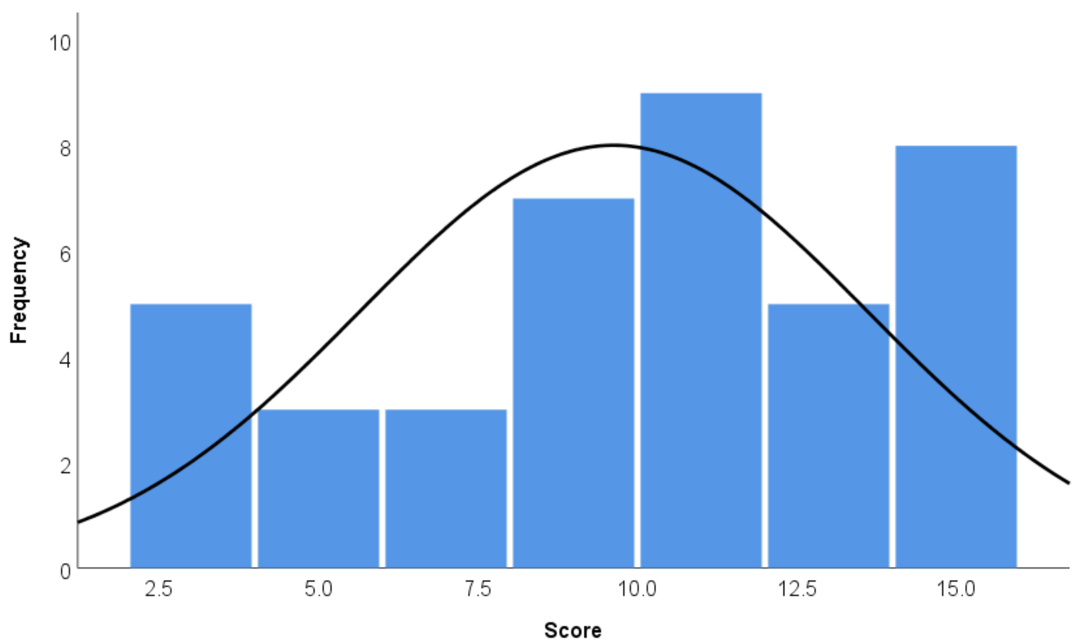


Figure E25

Histogram of Verbal Learning Proactive Interference for Minimally Processed Meals at 30 Minutes

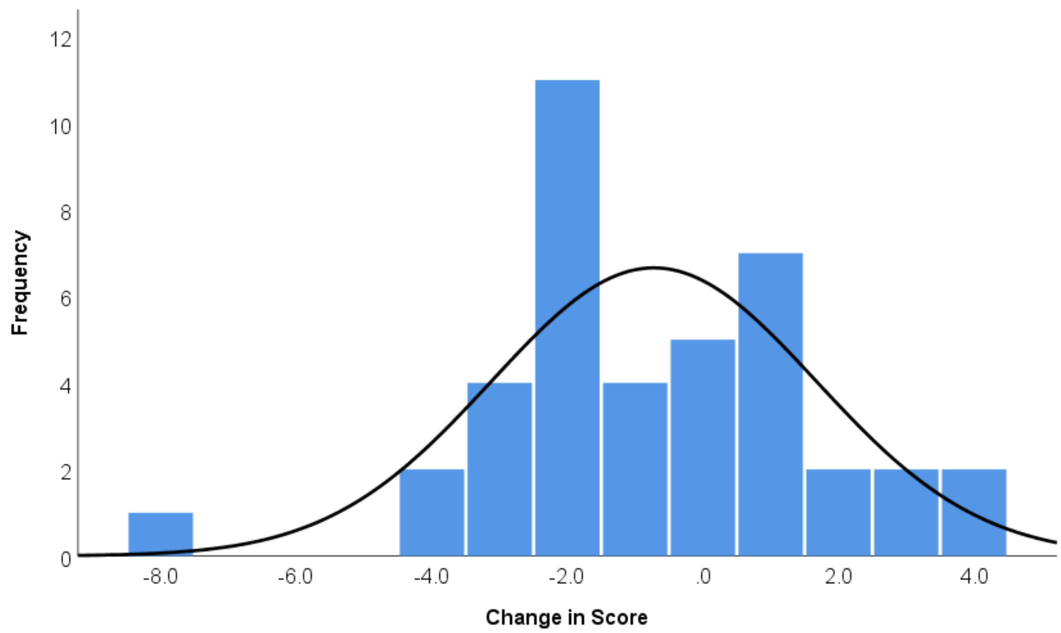


Figure E26

Histogram of Verbal Learning Proactive Interference for Minimally Processed Meals at 90 Minutes

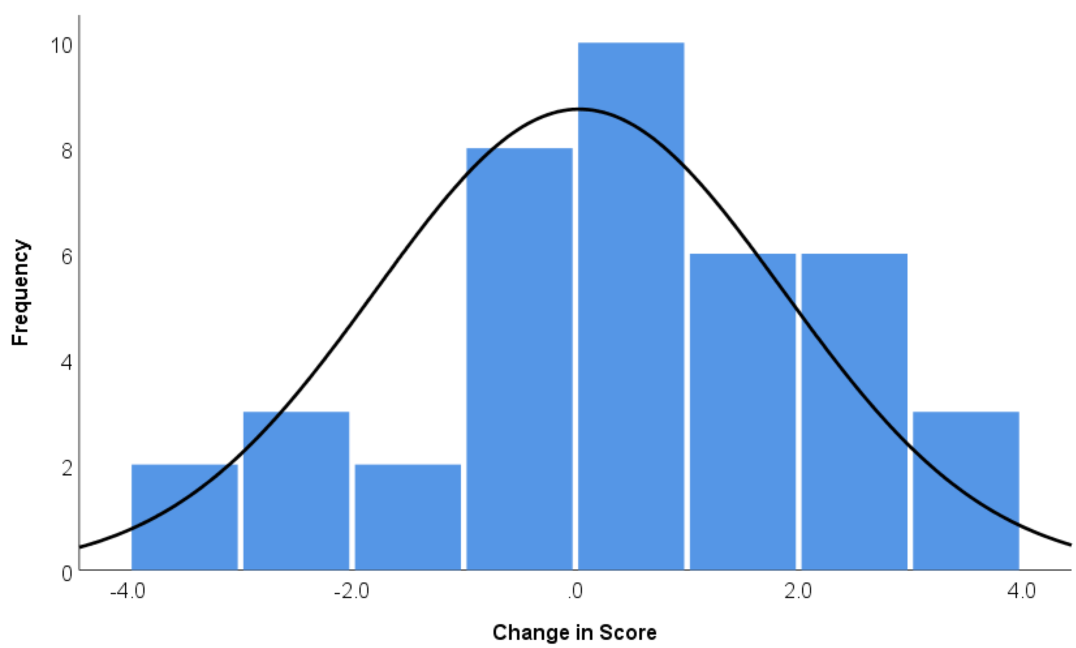


Figure E27

Histogram of Verbal Learning Proactive Interference for Ultra-Processed Meals at 30 Minutes

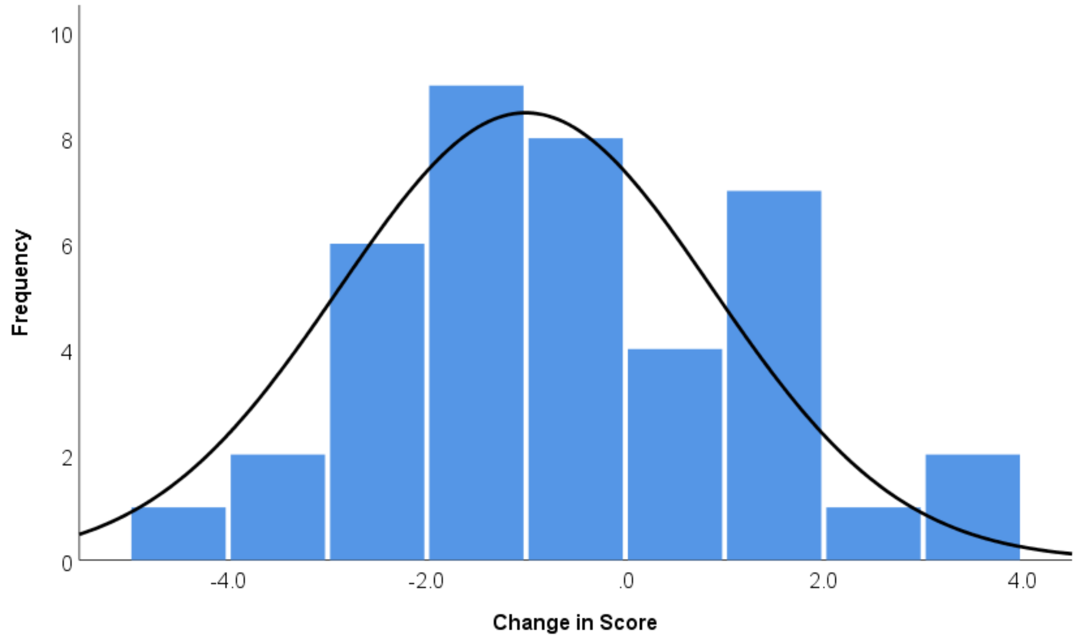


Figure E28

Histogram of Verbal Learning Proactive Interference for Ultra-Processed Meals at 90 Minute

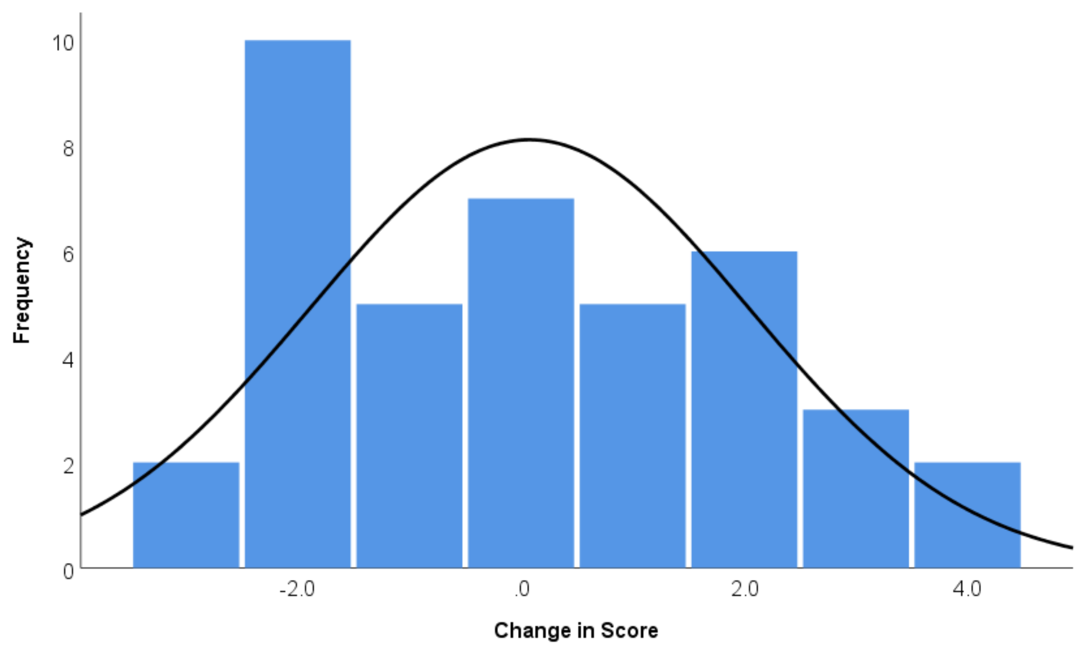


Figure E29

Histogram of Verbal Learning Retroactive Interference for Minimally Processed Meals at 30 Minutes

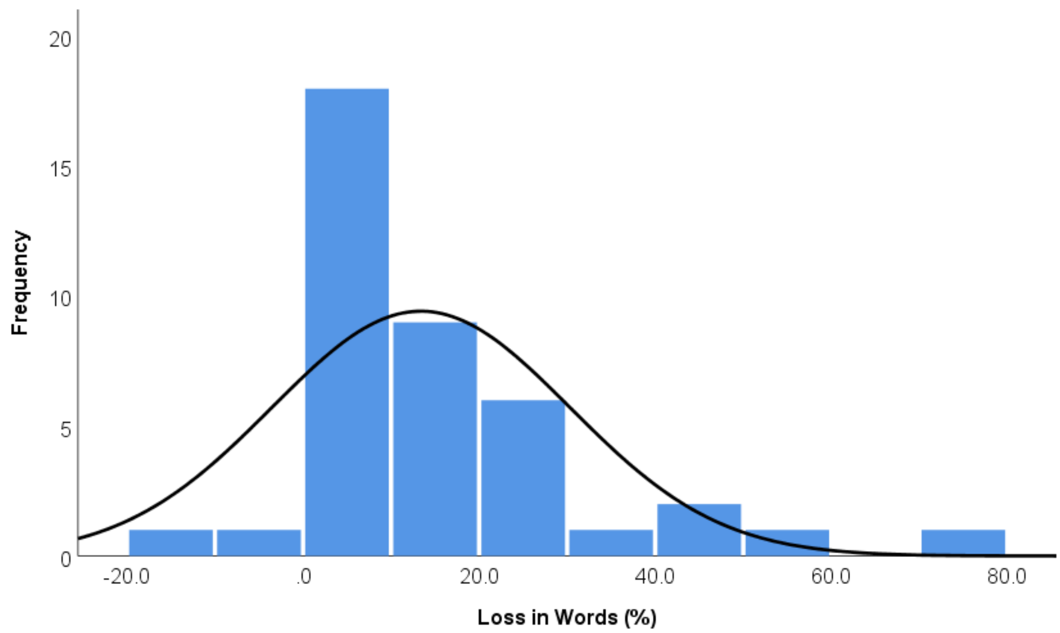


Figure E30

Histogram of Verbal Learning Retroactive Interference for Minimally Processed Meals at 90 Minutes

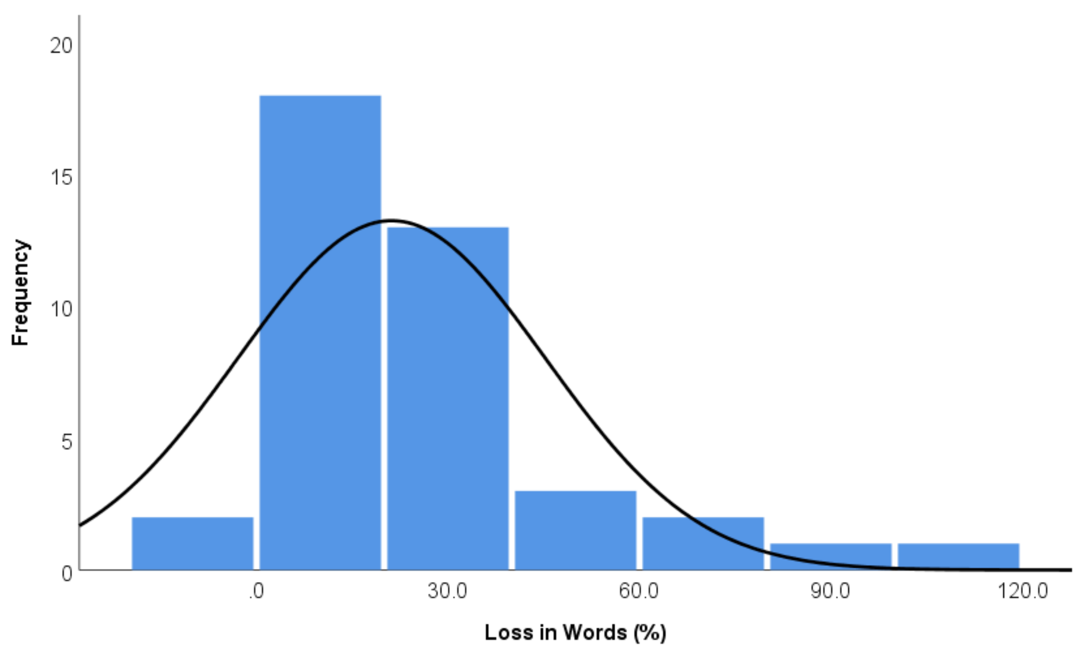


Figure E31

Histogram of Verbal Learning Retroactive Interference for Ultra-Processed Meals at 30 Minutes

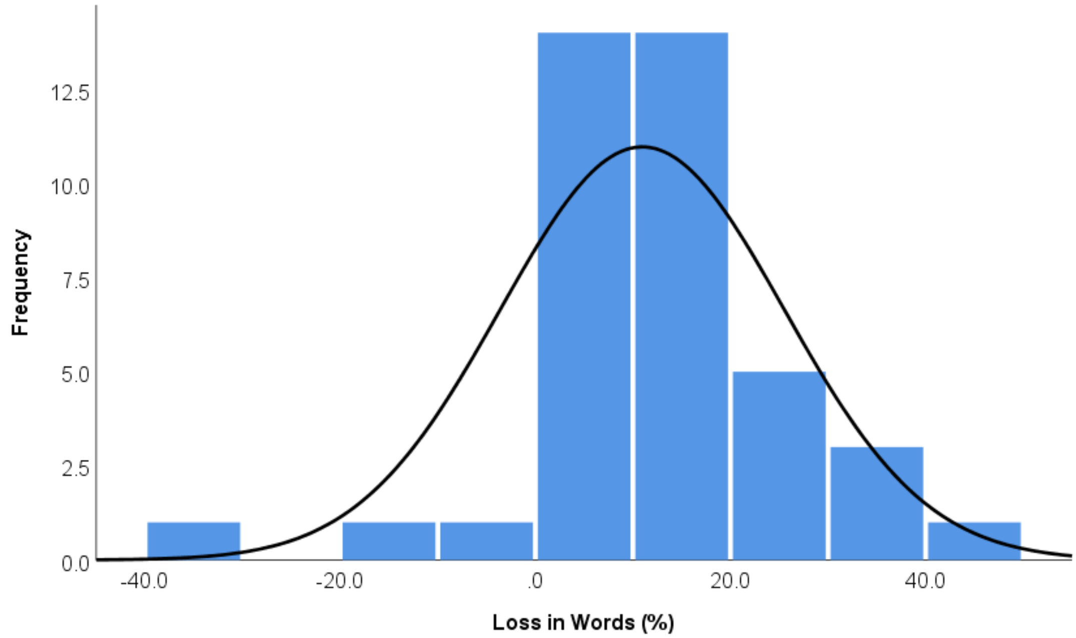


Figure E32

Histogram of Verbal Learning Retroactive Interference for Ultra-Processed Meals at 90 Minutes

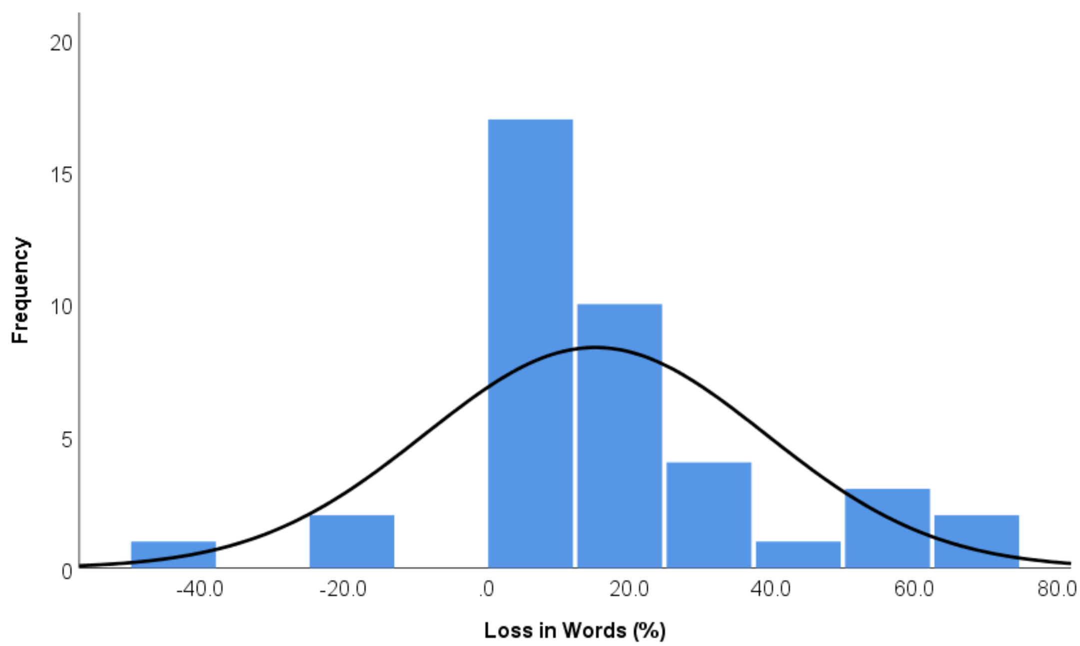


Figure E33

Histogram of Phonemic Fluency Score for Minimally Processed Meals at 30 Minutes

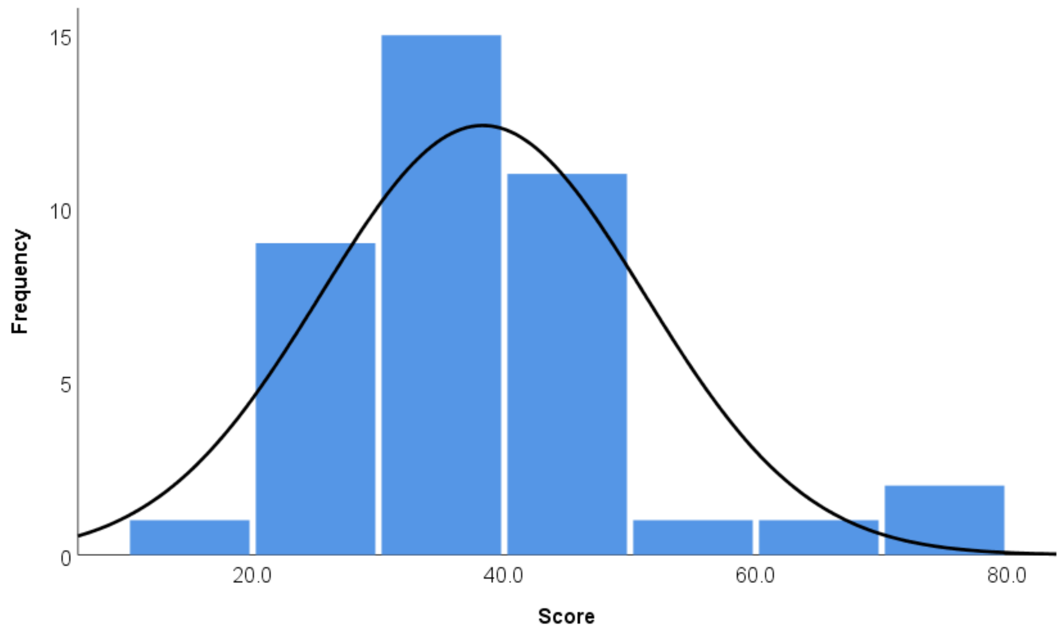


Figure E34

Histogram of Phonemic Fluency Score for Minimally Processed Meals at 90 Minutes

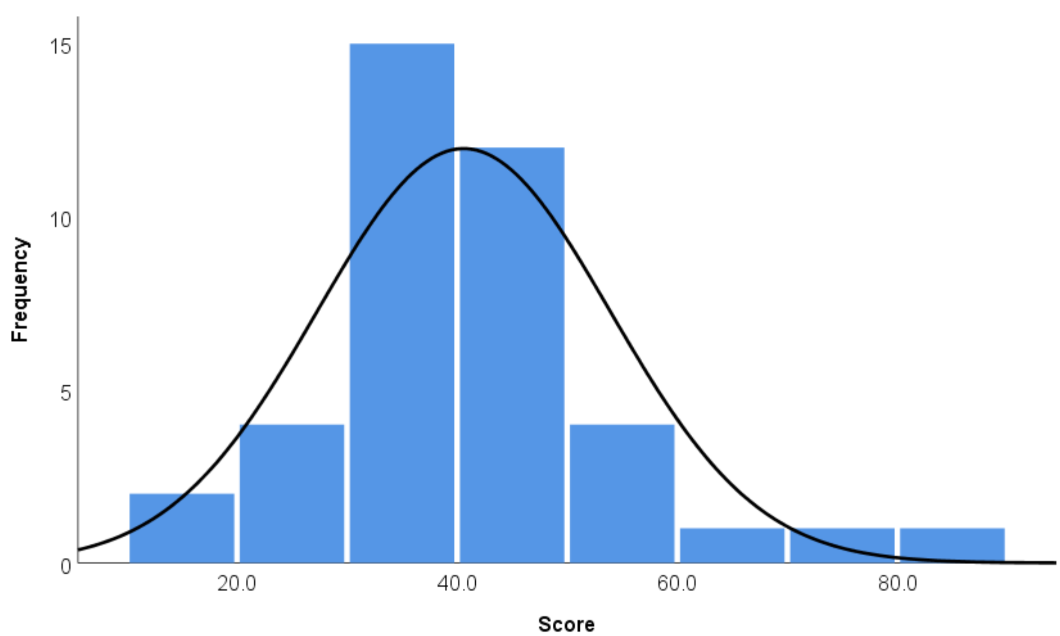


Figure E35

Histogram of Phonemic Fluency Score for Ultra-Processed Meals at 30 Minutes

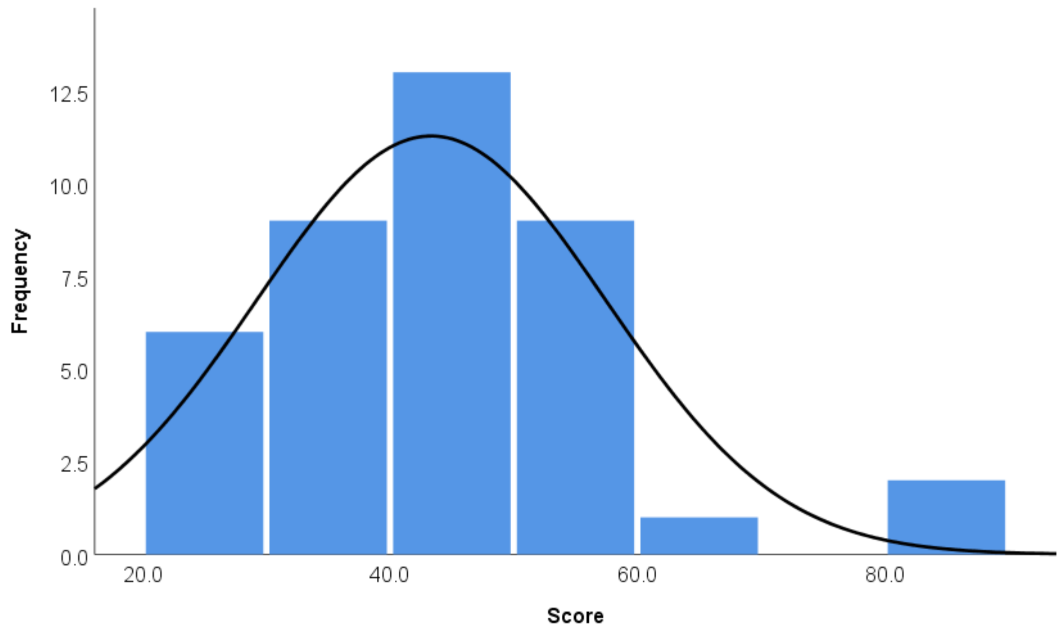


Figure E36

Histogram of Phonemic Fluency Score for Ultra-Processed Meals at 90 Minutes

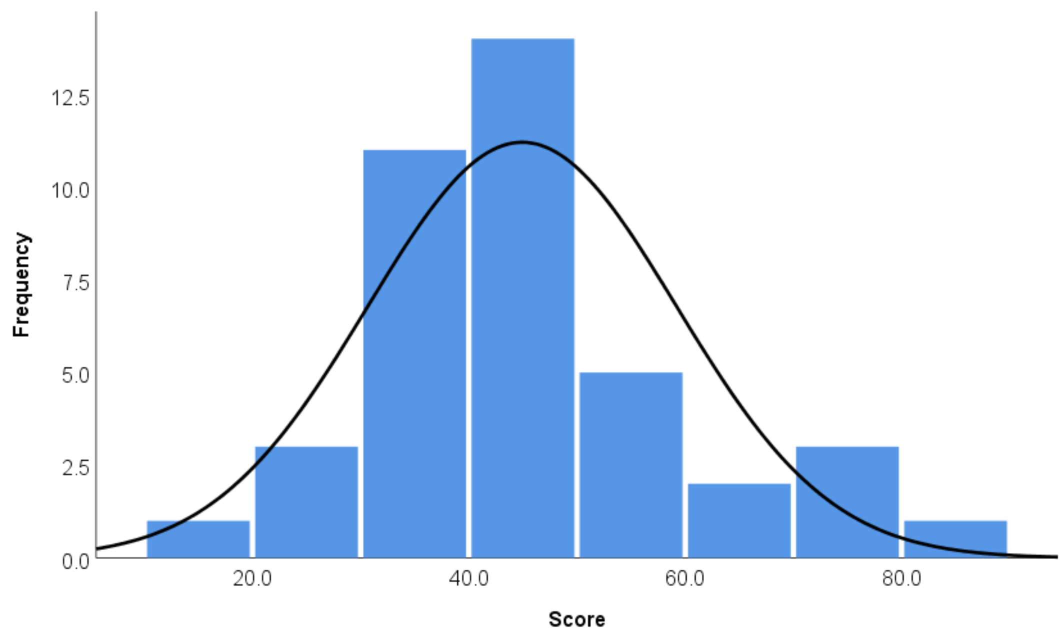


Figure E37

Histogram of Phonemic Fluency Perseverations for Minimally Processed Meals at 30 Minutes

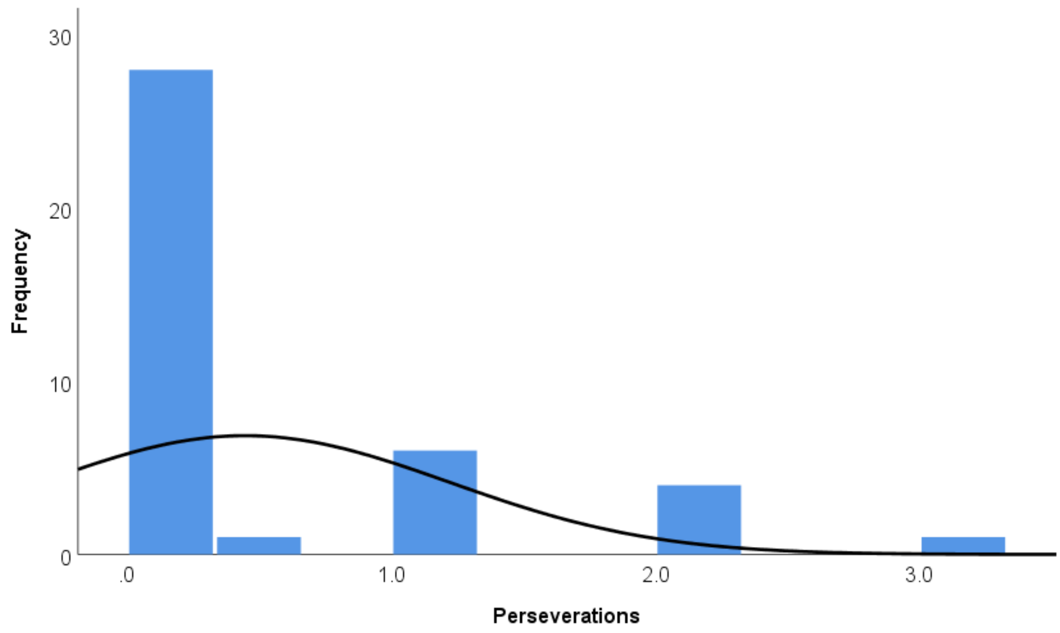


Figure E38

Histogram of Phonemic Fluency Perseverations for Minimally Processed Meals at 90 Minutes

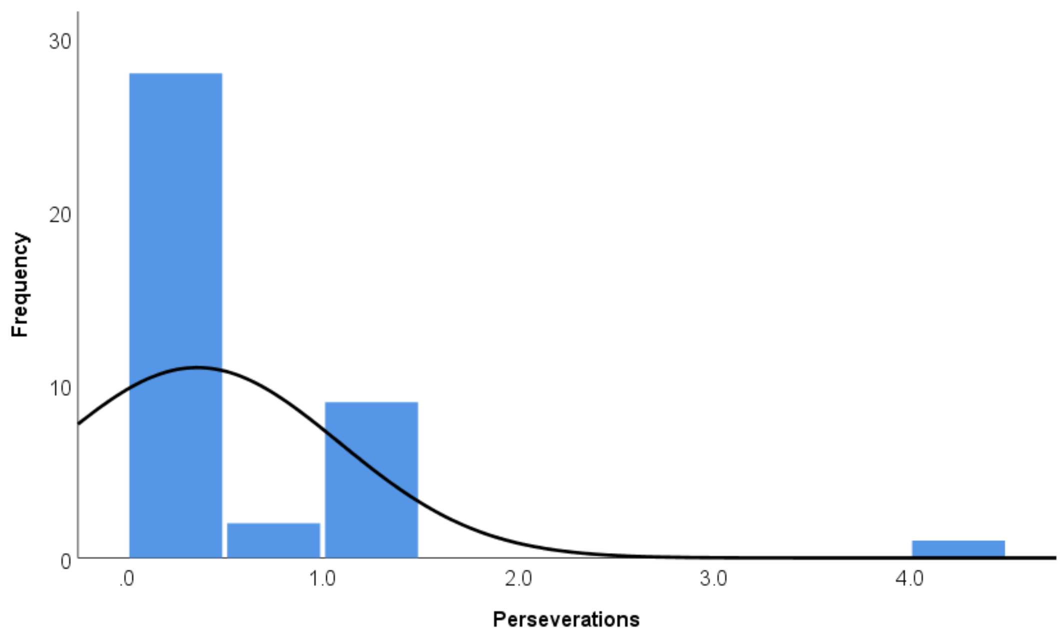


Figure E39

Histogram of Phonemic Fluency Perseverations for Ultra-Processed Meals at 30 Minutes

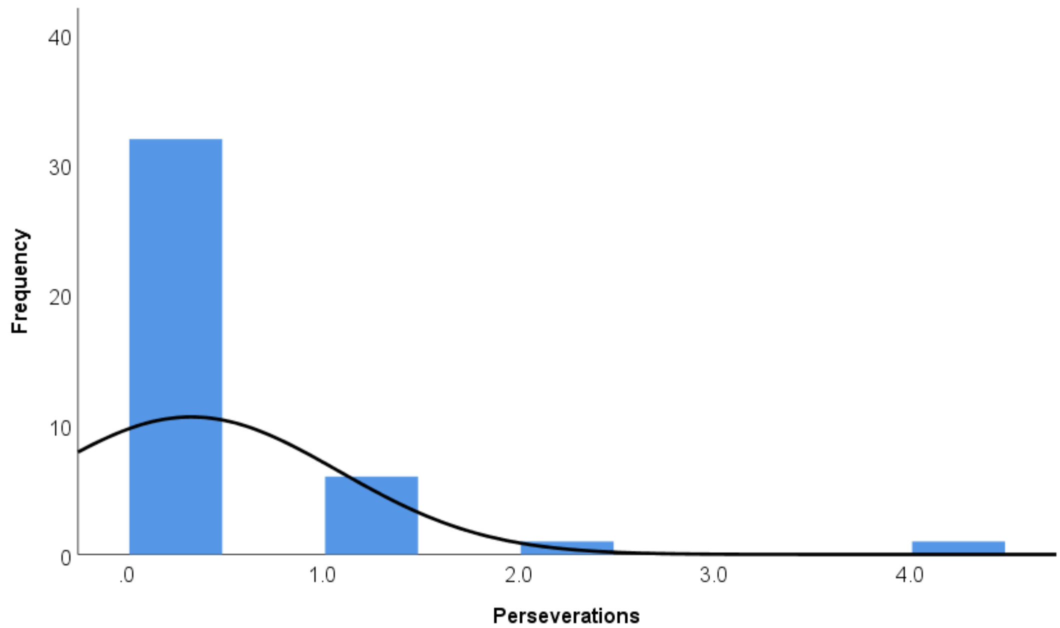


Figure E40

Histogram of Phonemic Fluency Perseverations for Ultra-Processed Meals at 90 Minutes

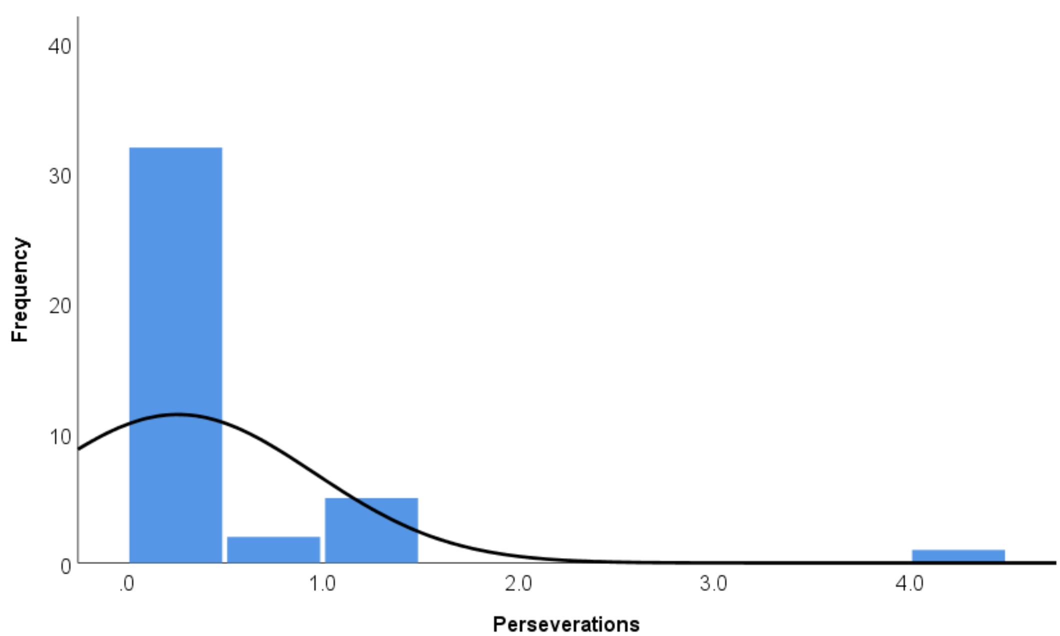


Figure E41

Histogram of Phonemic Fluency Intrusions for Minimally Processed Meals at 30 Minutes

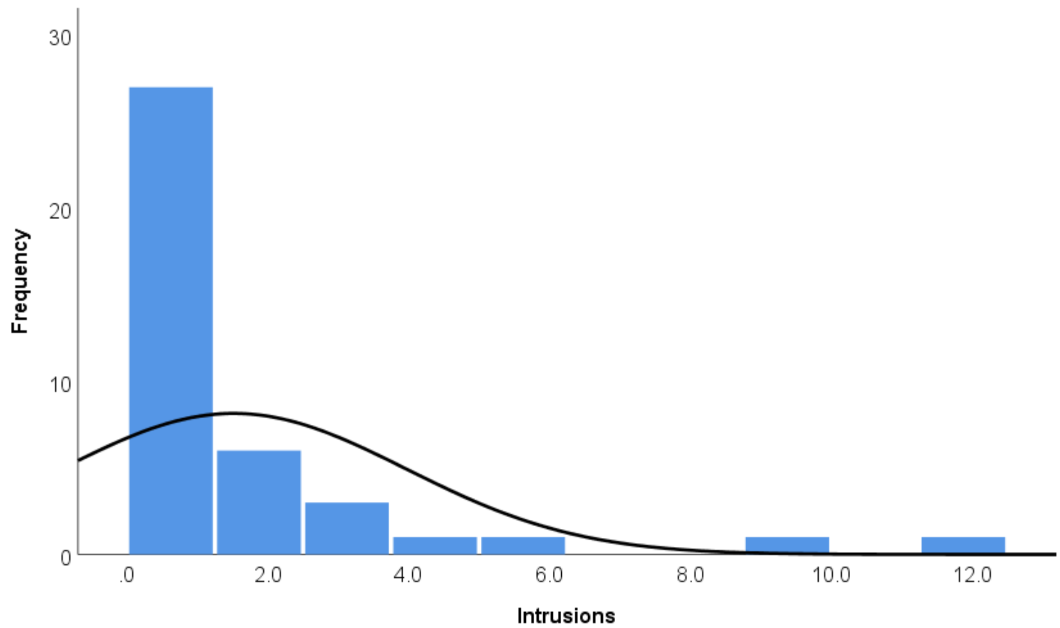


Figure E42

Histogram of Phonemic Fluency Intrusions for Minimally Processed Meals at 90 Minutes

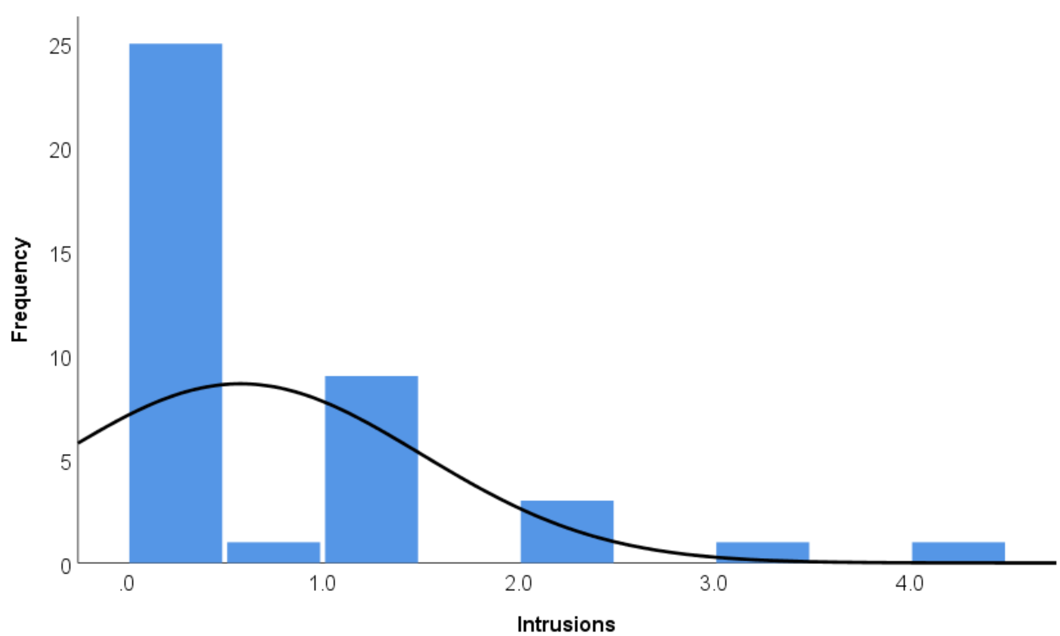


Figure E43

Histogram of Phonemic Fluency Intrusions for Ultra-Processed Meals at 30 Minutes

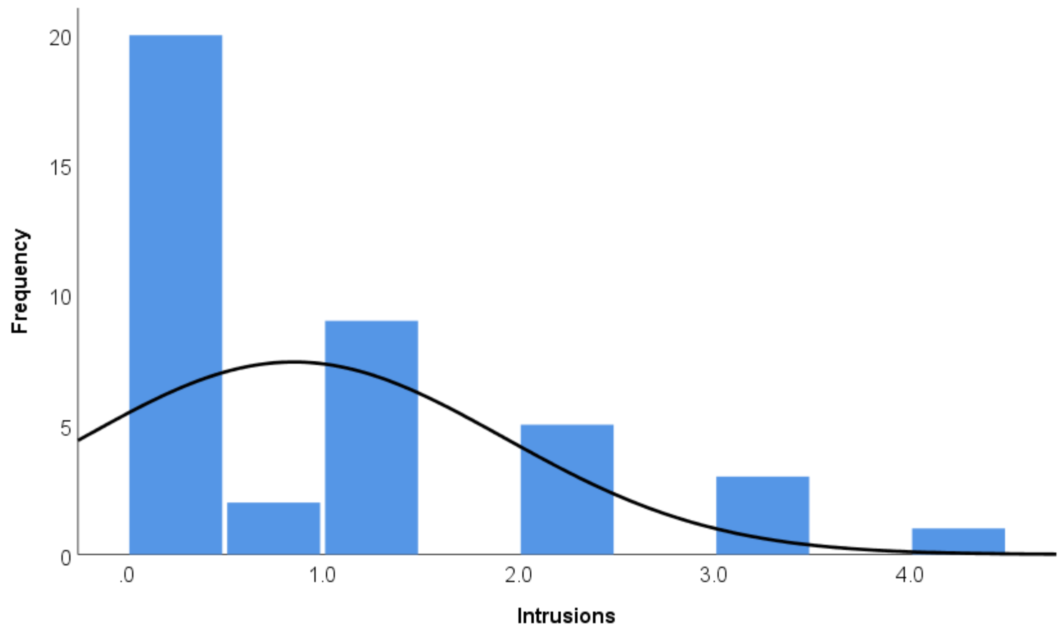


Figure E44

Histogram of Phonemic Fluency Intrusions for Ultra-Processed Meals at 90 Minutes

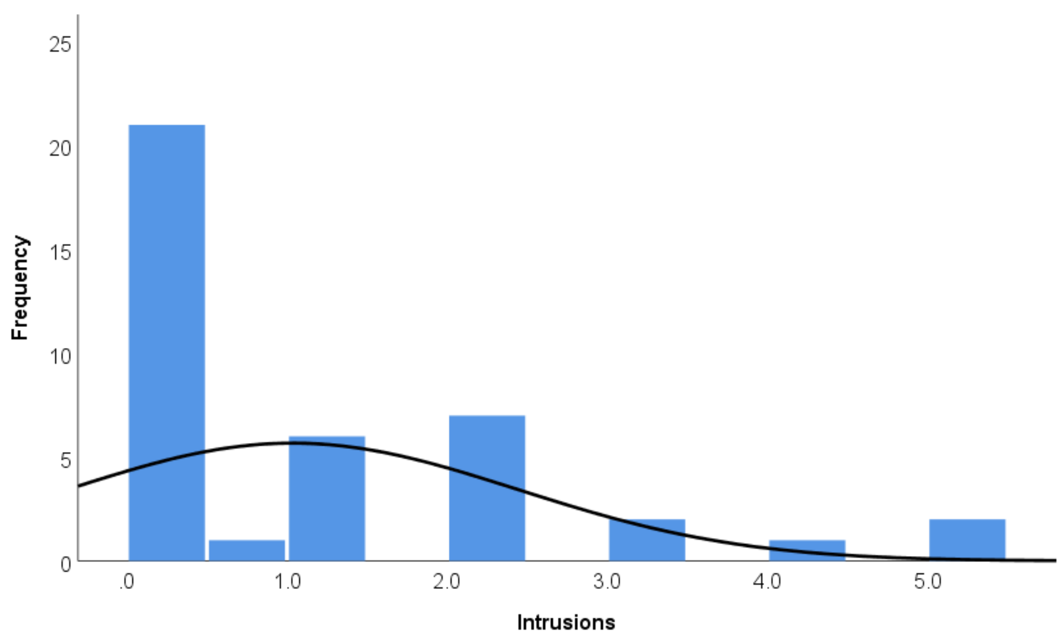


Figure E45

Histogram of Phonemic Fluency Switches for Minimally Processed Meals at 30 Minutes

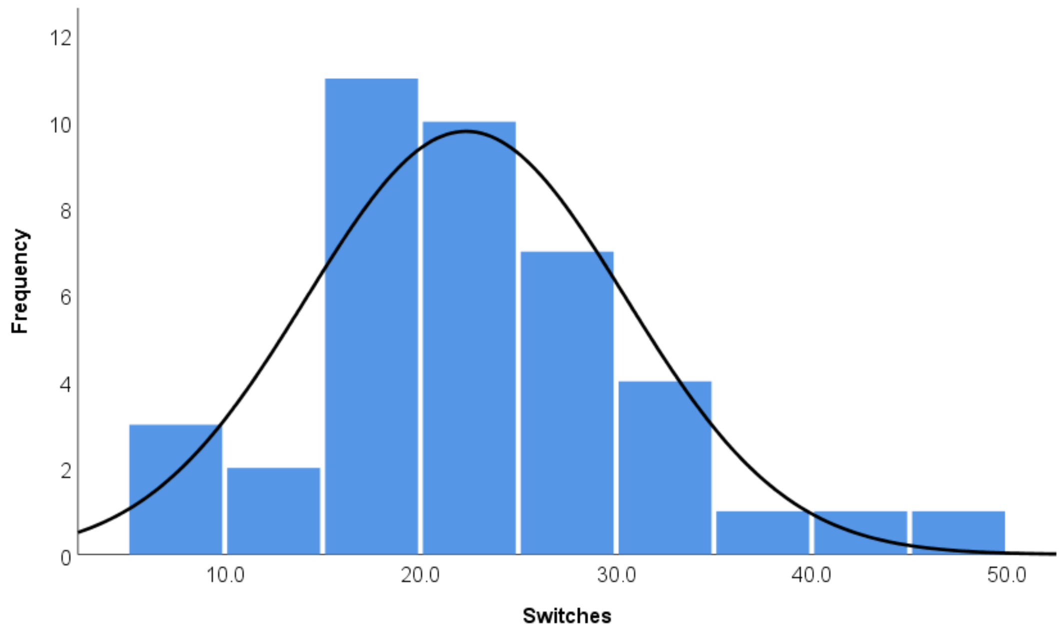


Figure E46

Histogram of Phonemic Fluency Switches for Minimally Processed Meals at 90 Minutes

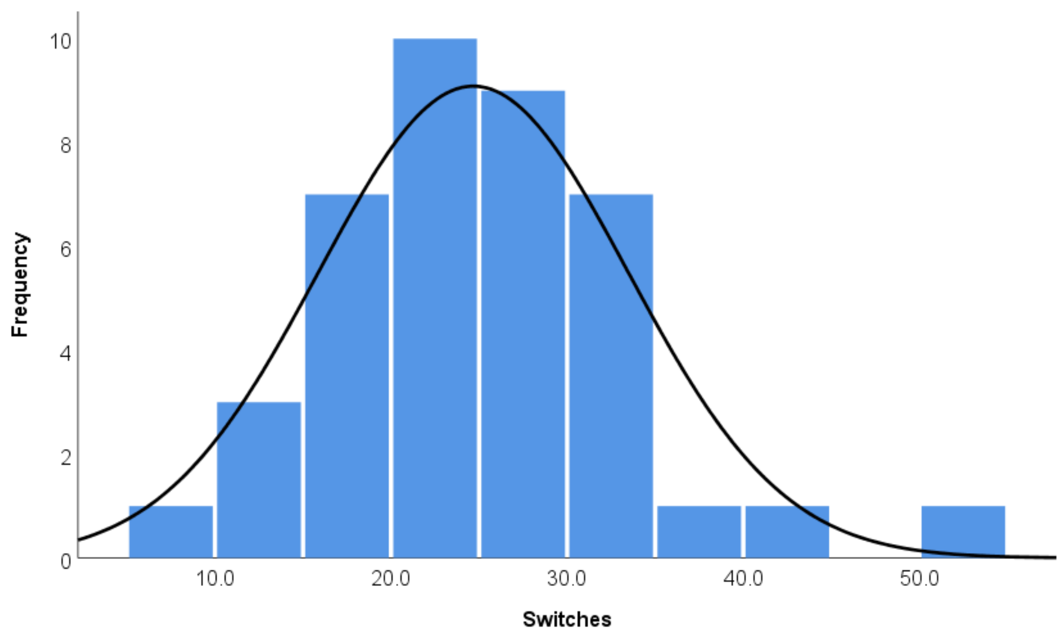


Figure E47

Histogram of Phonemic Fluency Switches for Ultra-Processed Meals at 30 Minutes

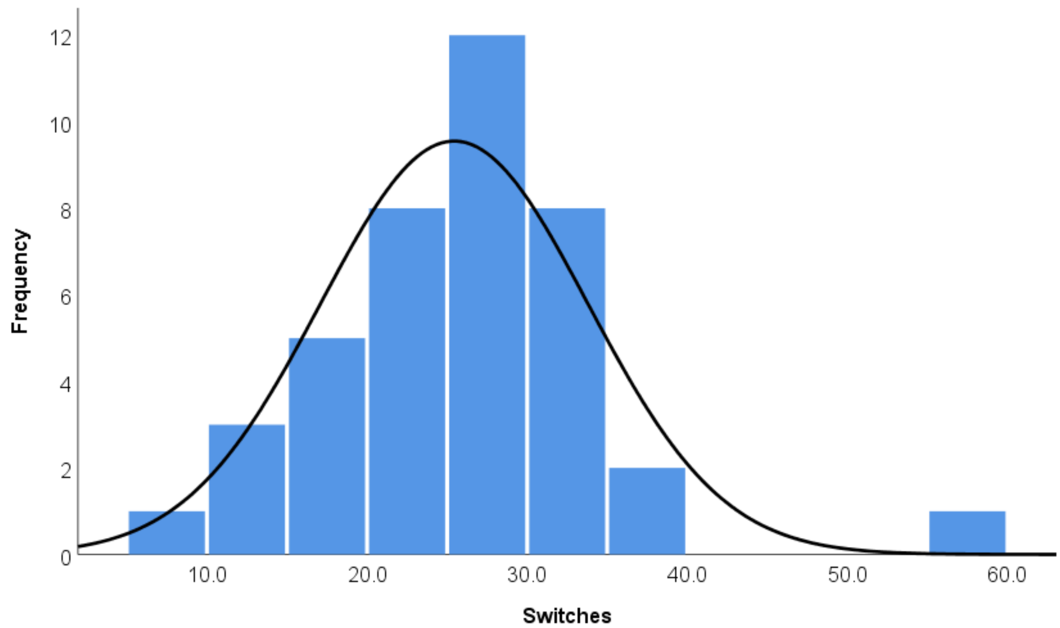


Figure E48

Histogram of Phonemic Fluency Switches for Ultra-Processed Meals at 90 Minutes

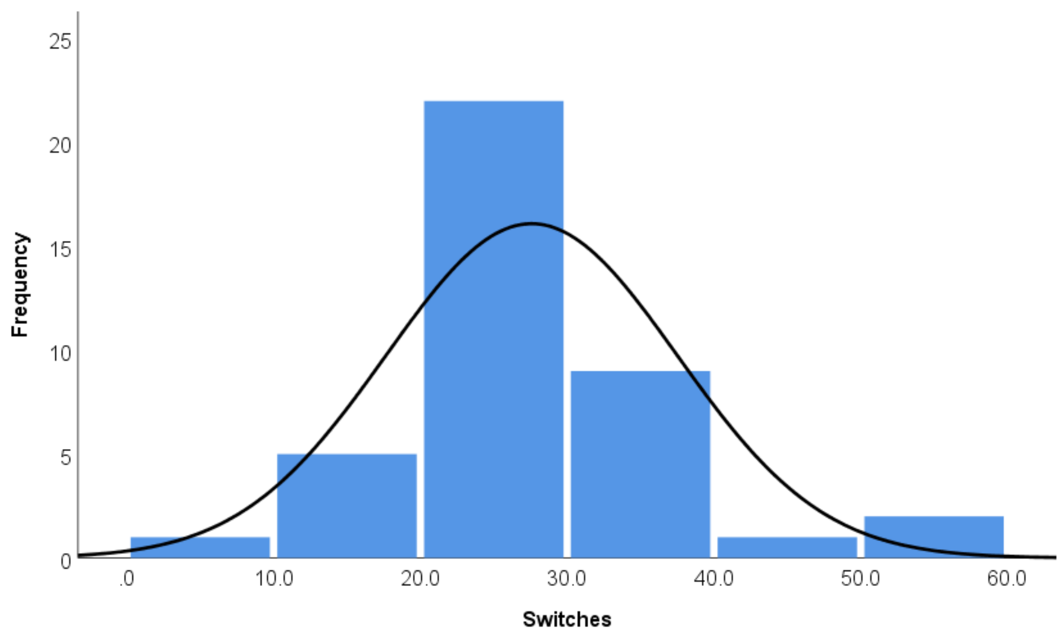


Figure E49

Histogram of Phonemic Fluency Total Cluster Size for Minimally Processed Meals at 30 Minutes

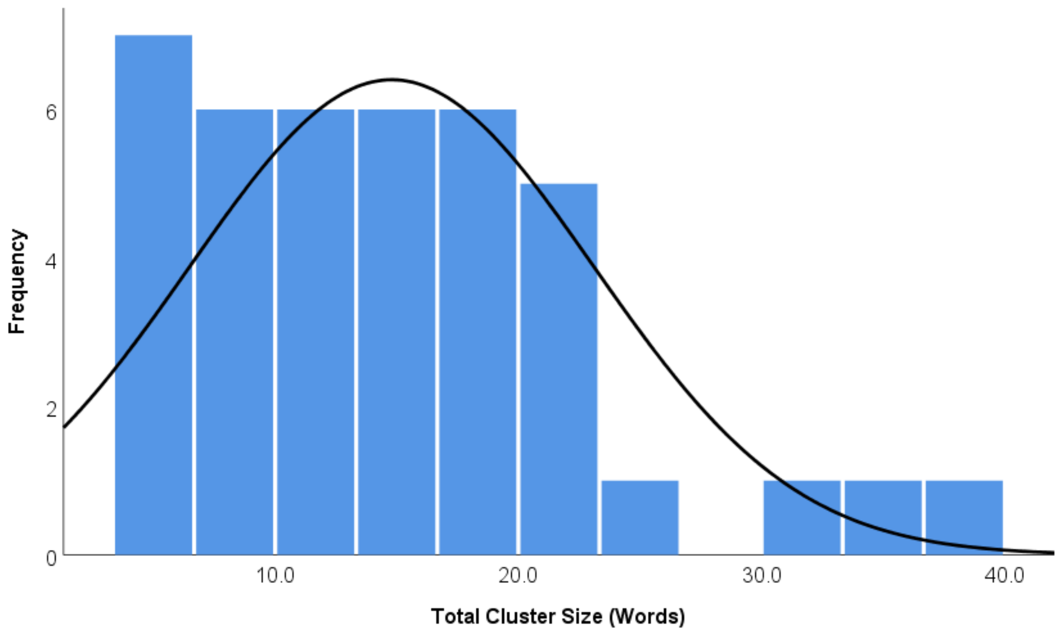


Figure E50

Histogram of Phonemic Fluency Total Cluster Size for Minimally Processed Meals at 90 Minutes

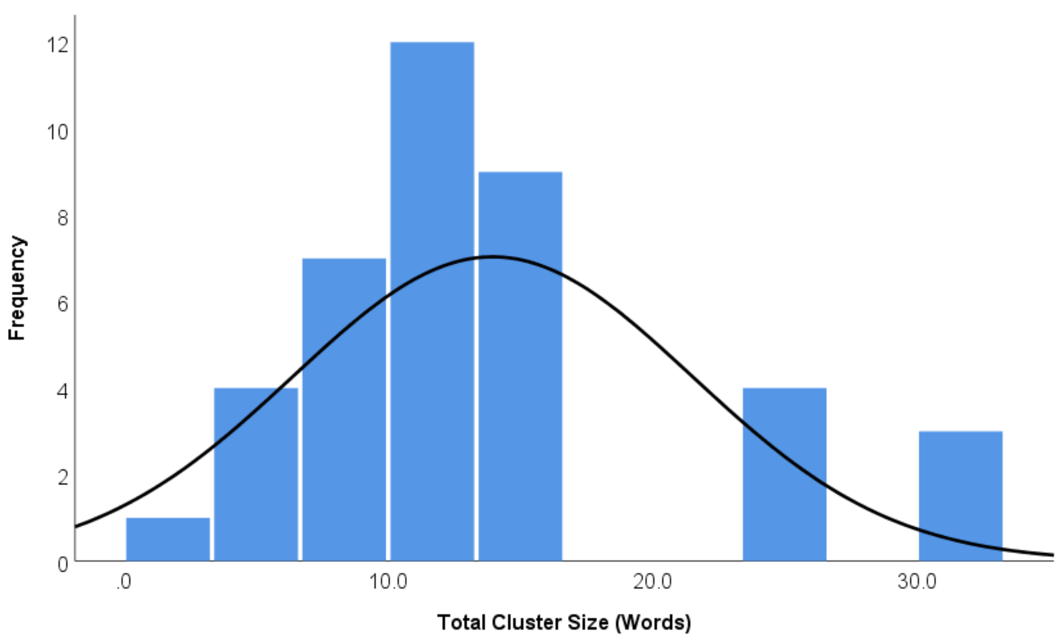


Figure E51

Histogram of Phonemic Fluency Total Cluster Size for Ultra-Processed Meals at 30 Minutes

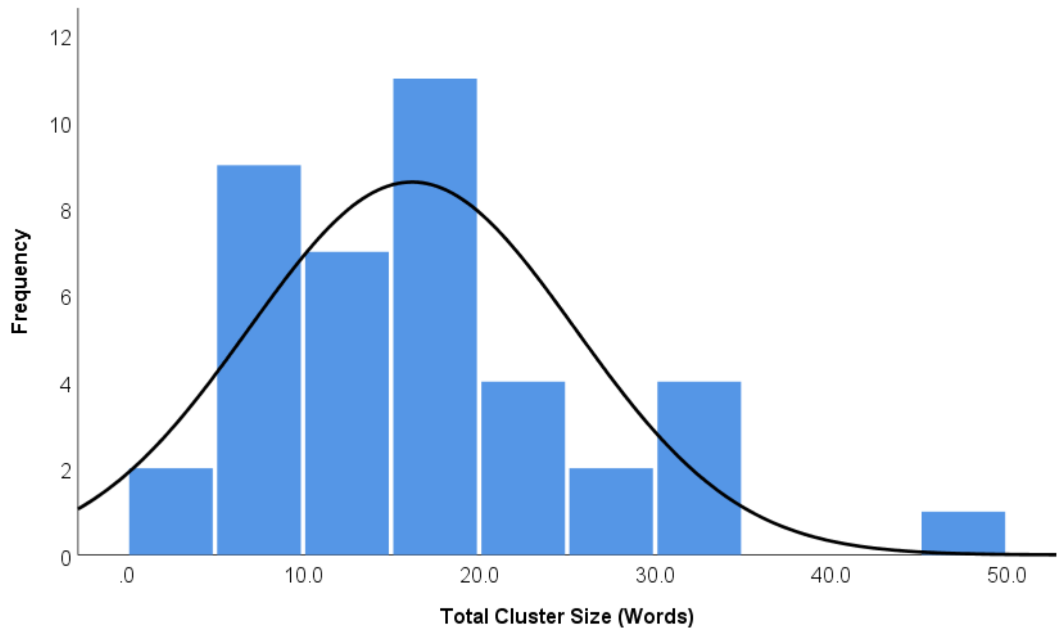


Figure E52

Histogram of Phonemic Fluency Total Cluster Size for Ultra-Processed Meals at 90 Minutes

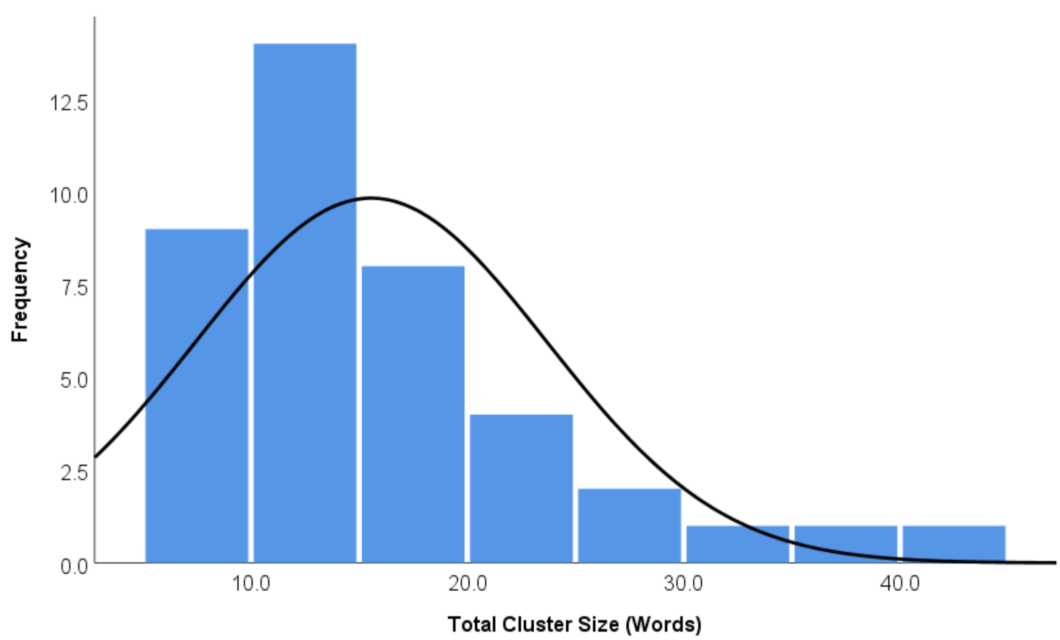


Figure E53

Histogram of Phonemic Fluency Average Cluster Size for Minimally Processed Meals at 30 Minutes

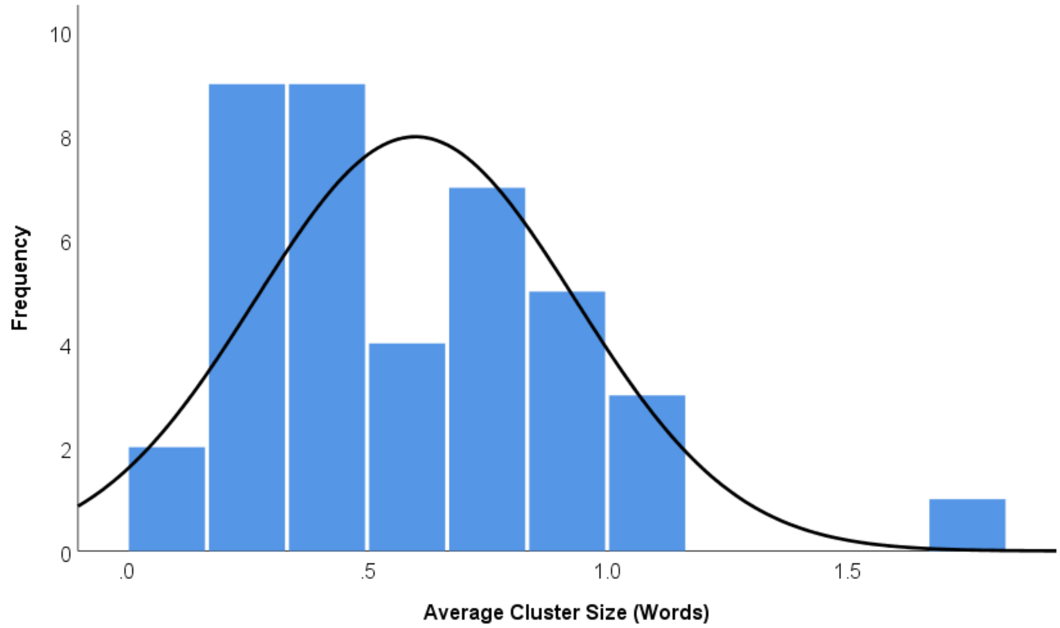


Figure E54

Histogram of Phonemic Fluency Average Cluster Size for Minimally Processed Meals at 90 Minutes

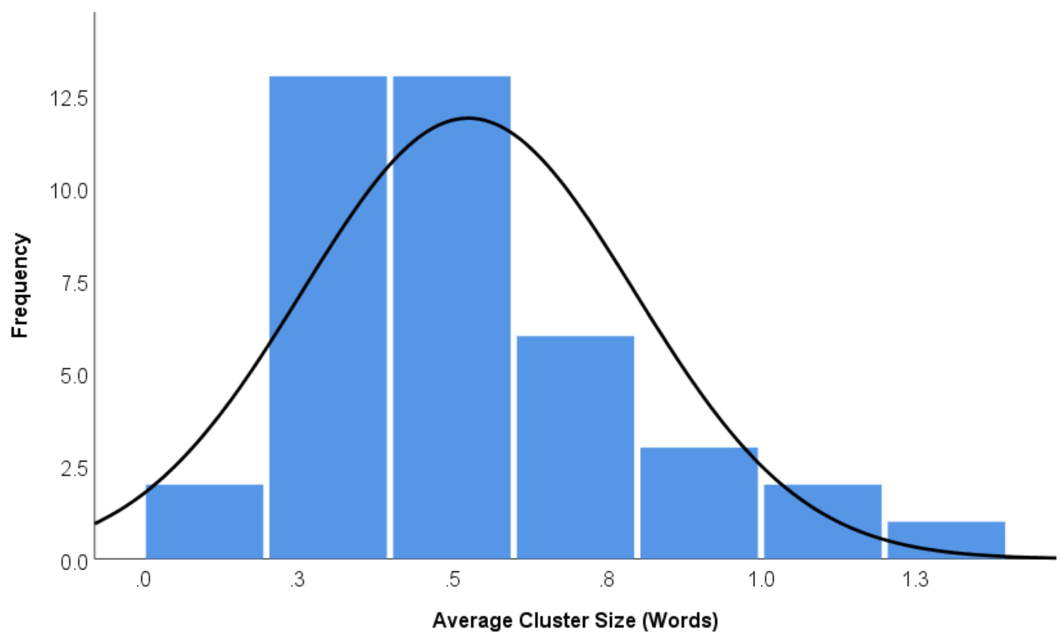


Figure E55

Histogram of Phonemic Fluency Average Cluster Size for Ultra-Processed Meals at 30 Minutes

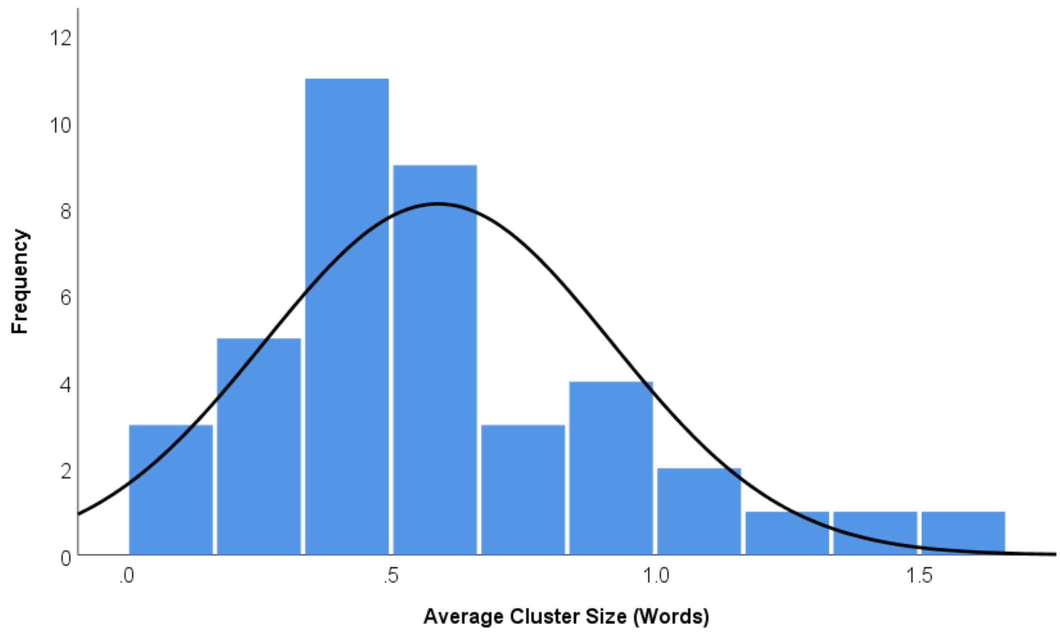


Figure E56

Histogram of Phonemic Fluency Average Cluster Size for Ultra-Processed Meals at 90 Minutes

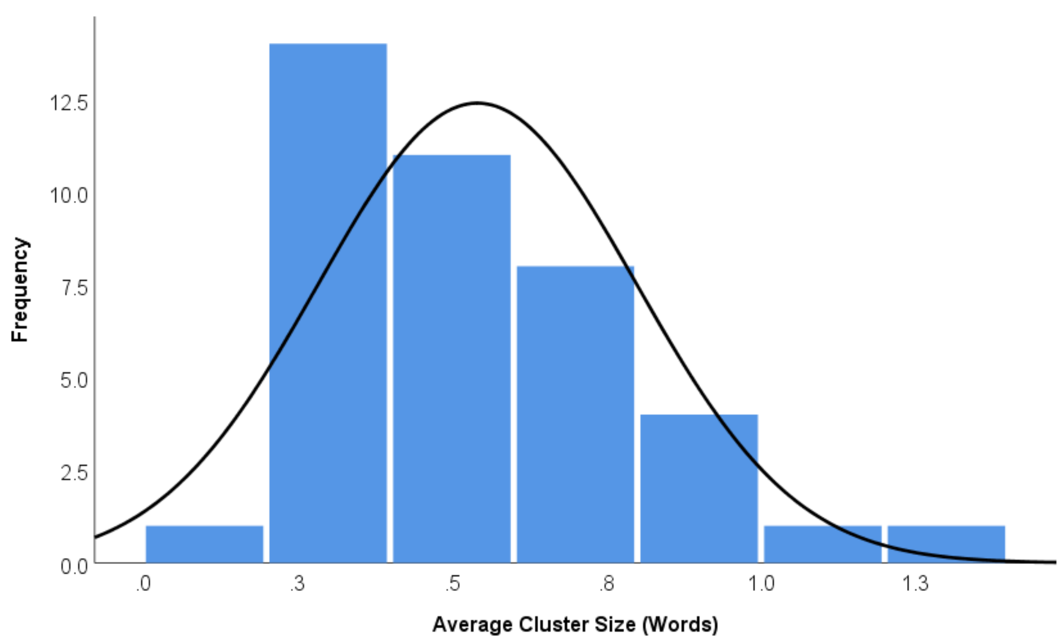


Figure E57

Histogram of Semantic Fluency Score for Minimally Processed Meals at 30 Minutes

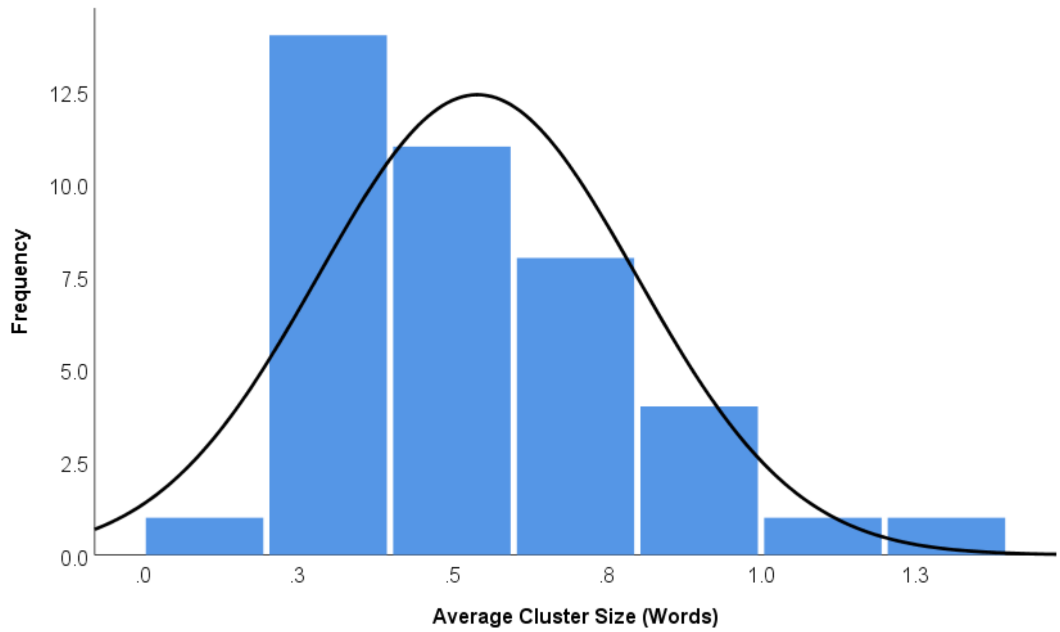


Figure E58

Histogram of Semantic Fluency Score for Minimally Processed Meals at 90 Minutes

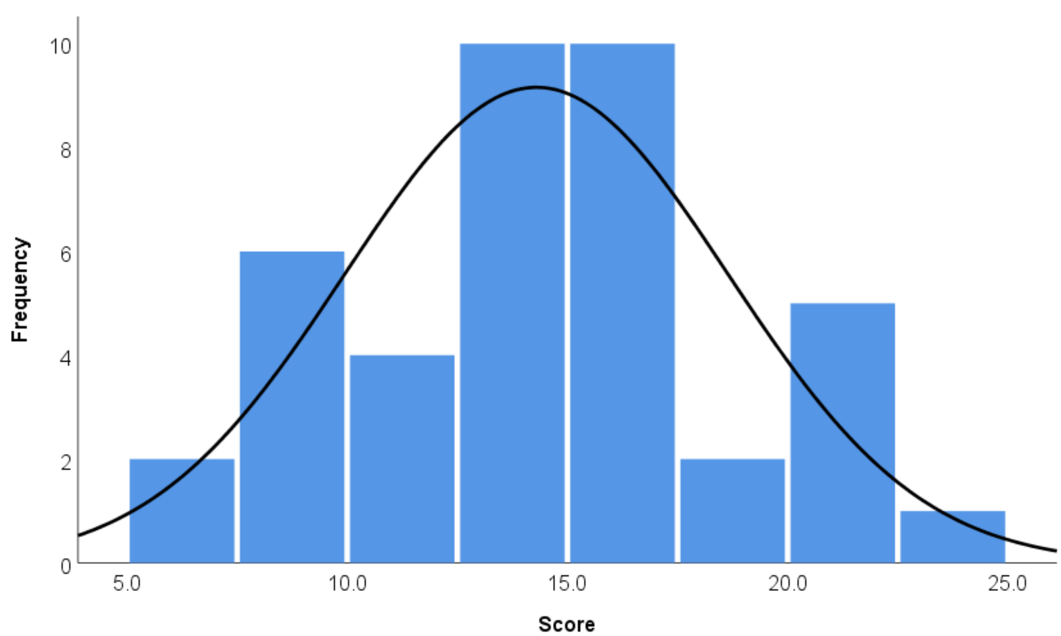


Figure E59

Histogram of Semantic Fluency Score for Ultra-Processed Meals at 30 Minutes

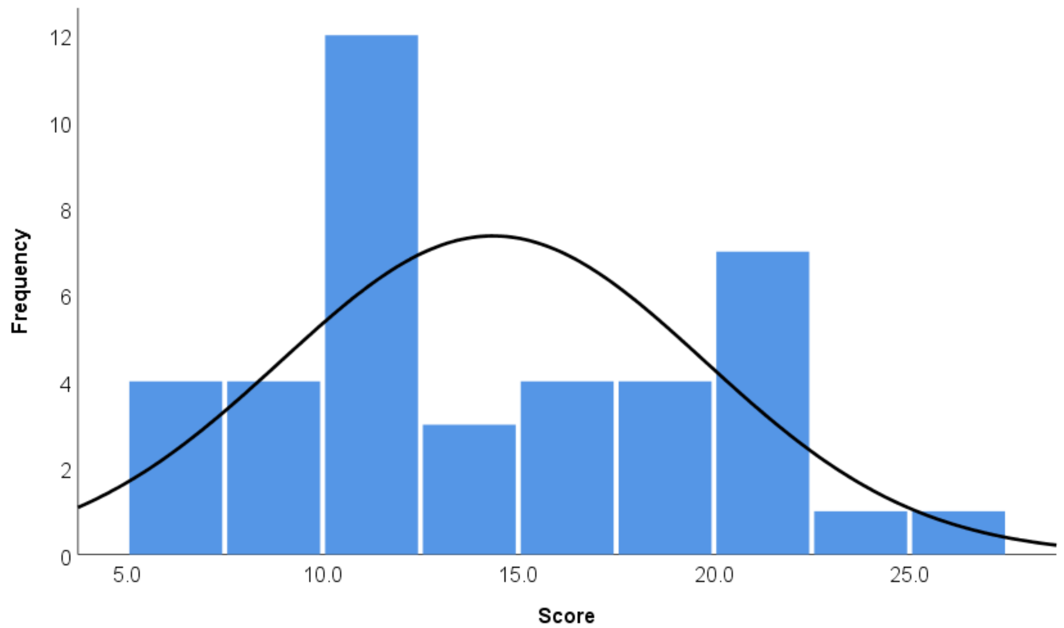


Figure E60

Histogram of Semantic Fluency Score for Ultra-Processed Meals at 90 Minutes

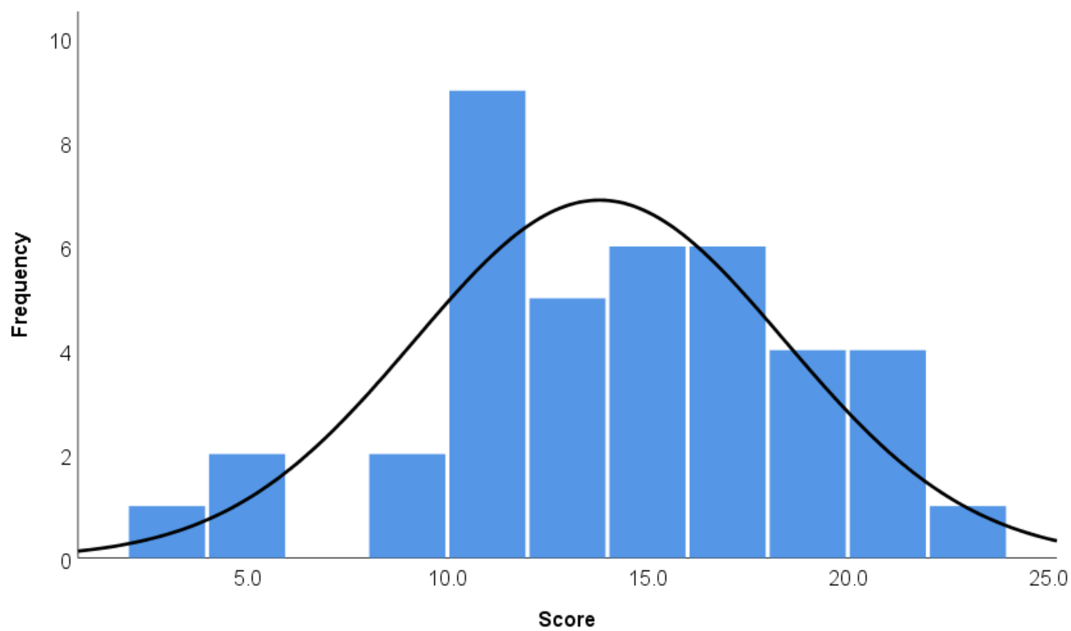


Figure E61

Histogram of Semantic Fluency Perseverations for Minimally Processed Meals at 30 Minutes

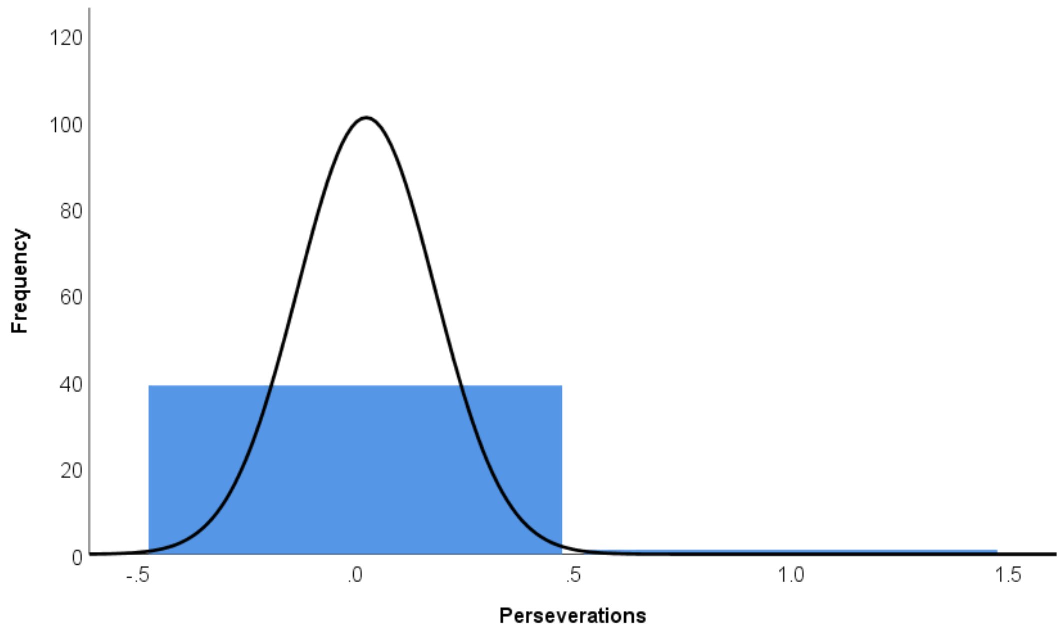


Figure E62

Histogram of Semantic Fluency Perseverations for Minimally Processed Meals at 90 Minutes

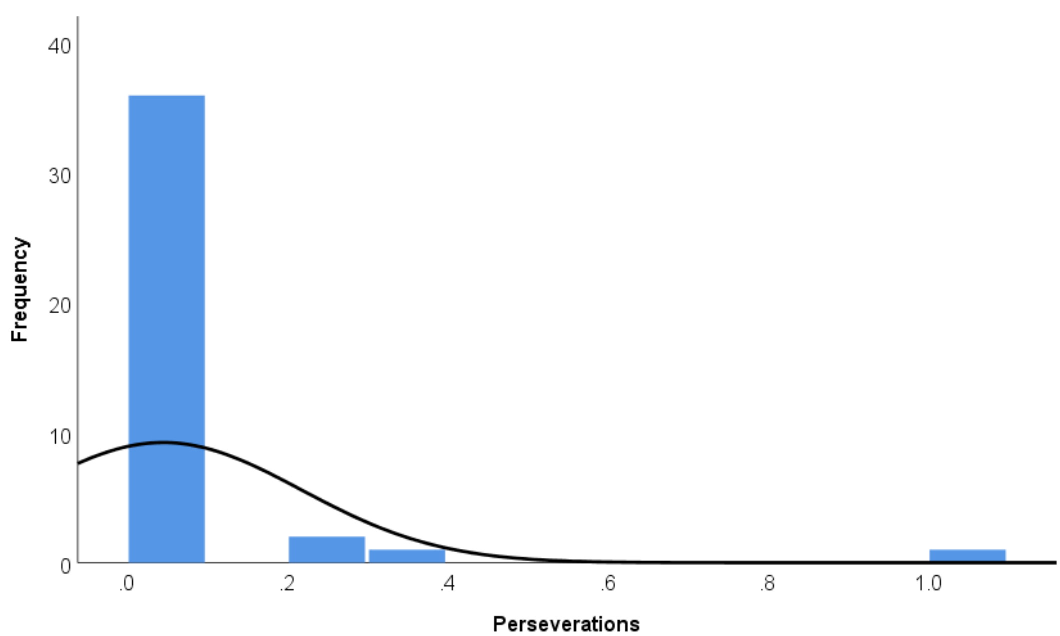


Figure E63

Histogram of Semantic Fluency Perseverations for Ultra-Processed Meals at 30 Minutes

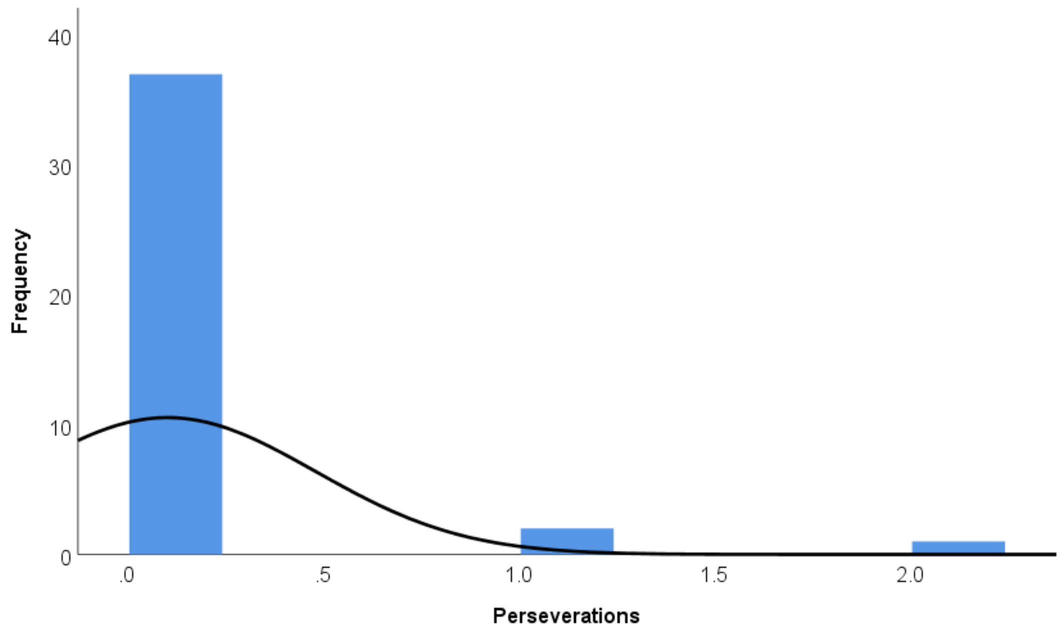


Figure E64

Histogram of Semantic Fluency Perseverations for Ultra-Processed Meals at 90 Minutes

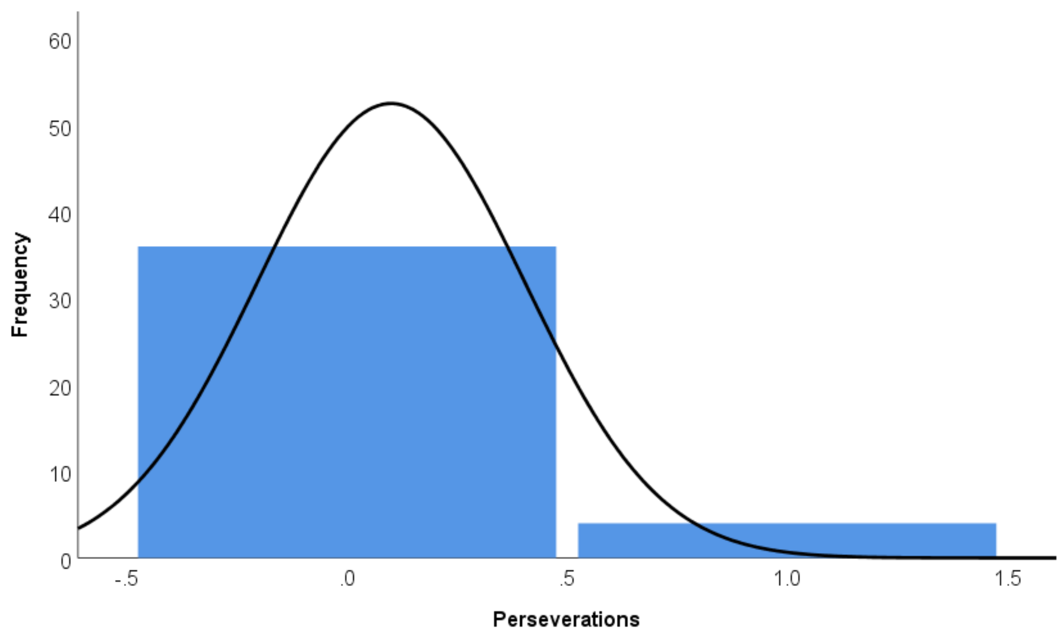


Figure E65

Histogram of Semantic Fluency Intrusions for Minimally Processed Meals at 30 Minutes

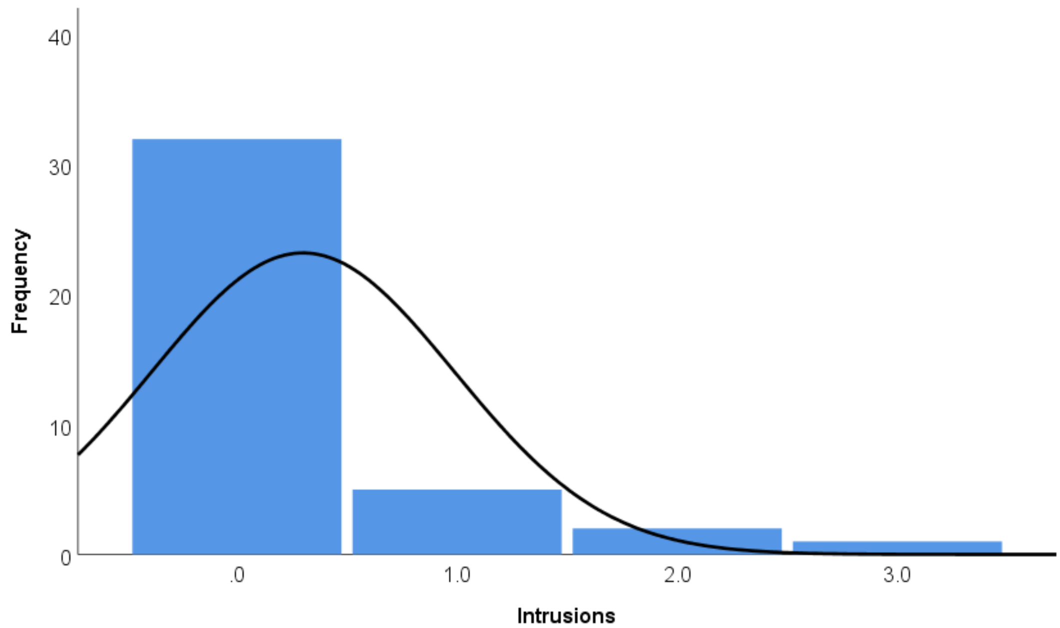


Figure E66

Histogram of Semantic Fluency Intrusions for Minimally Processed Meals at 90 Minutes

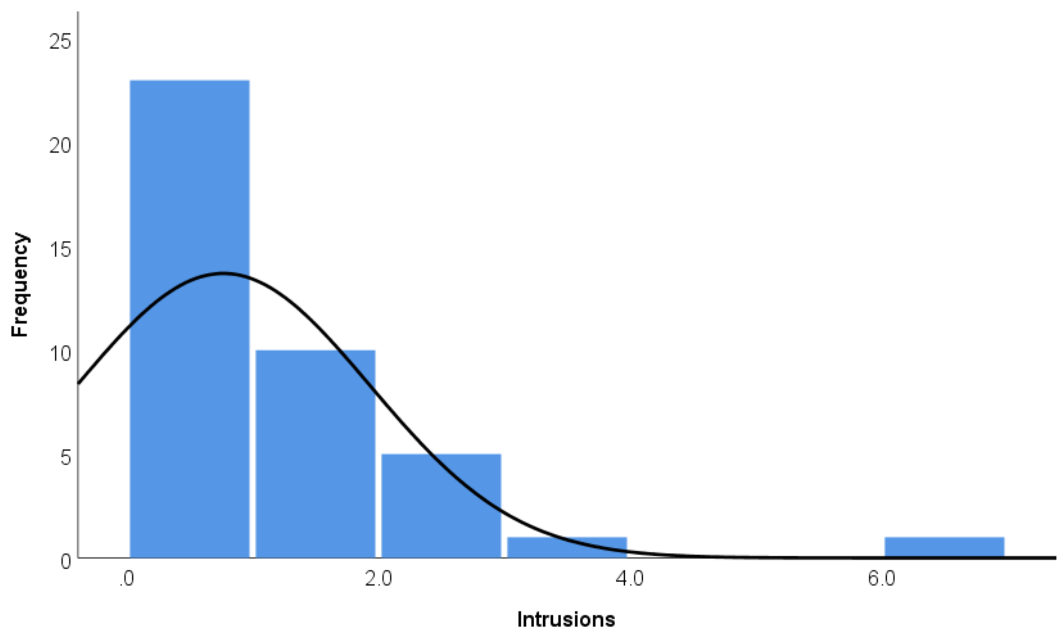


Figure E67

Histogram of Semantic Fluency Intrusions for Ultra-Processed Meals at 30 Minutes

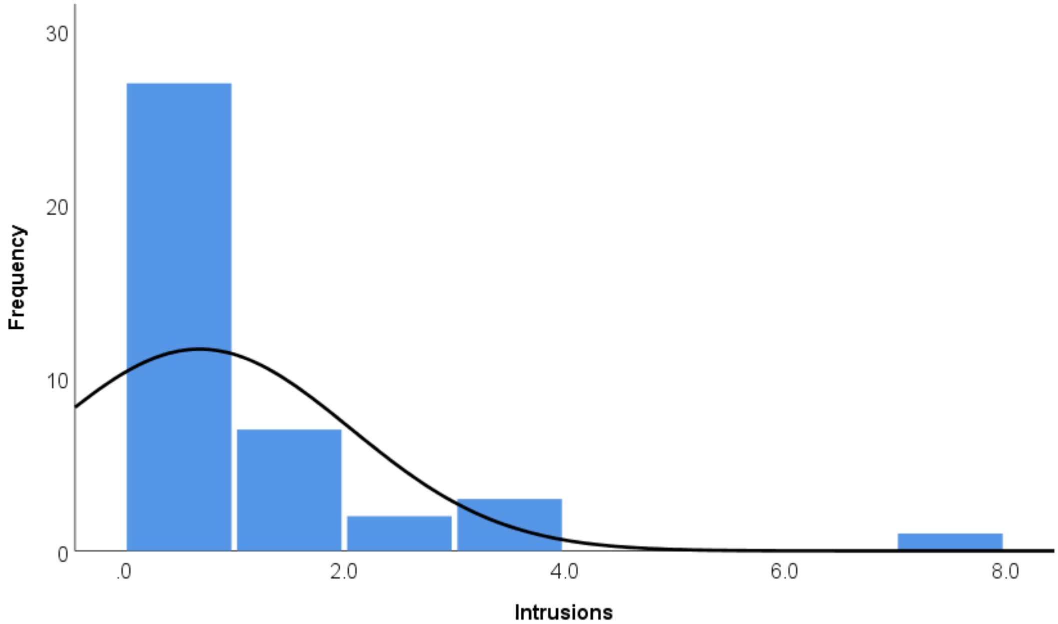


Figure E68

Histogram of Semantic Fluency Intrusions for Ultra-Processed Meals at 90 Minutes

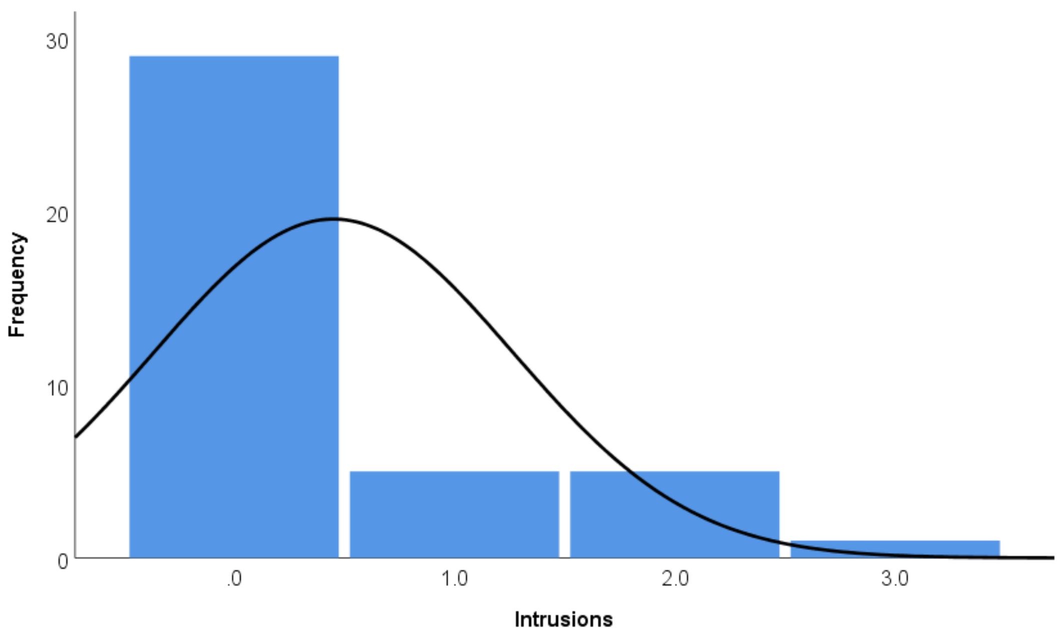


Figure E69

Histogram of Semantic Fluency Switches for Minimally Processed Meals at 30 Minutes

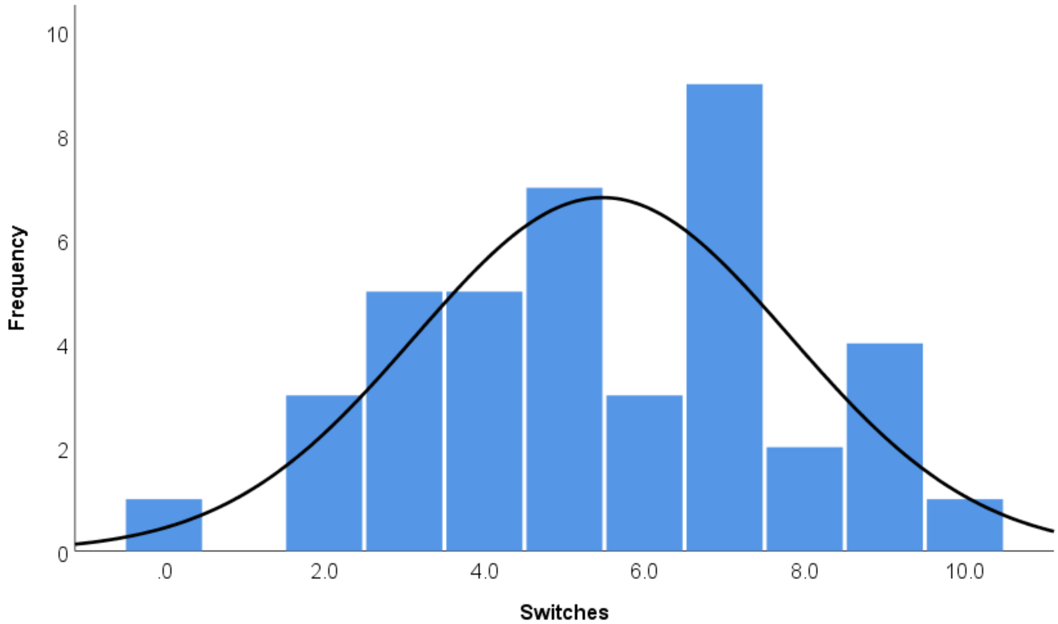


Figure E70

Histogram of Semantic Fluency Switches for Minimally Processed Meals at 90 Minutes

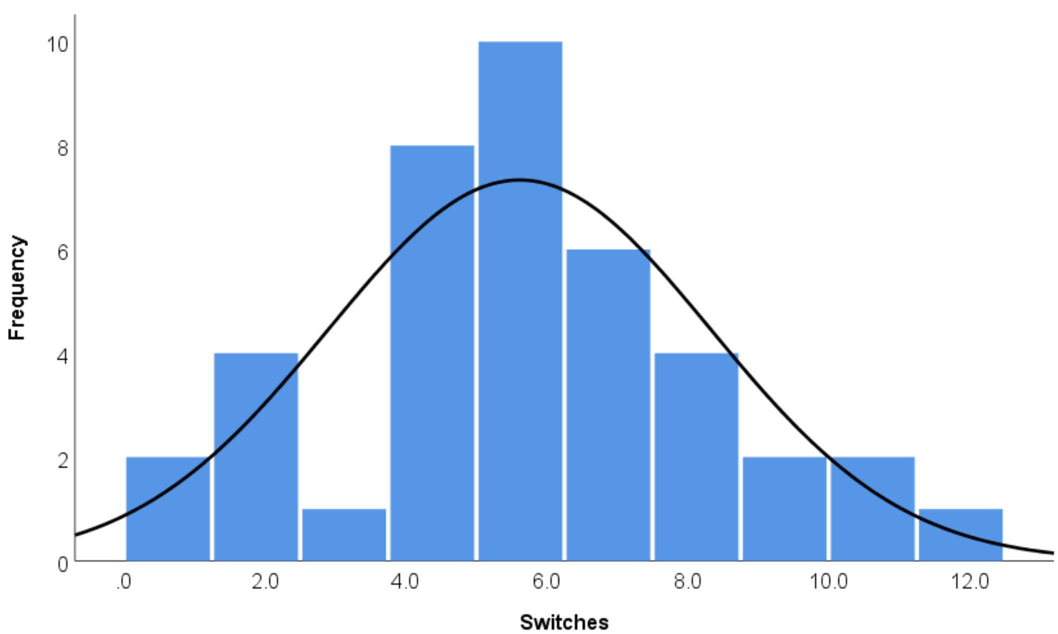


Figure E71

Histogram of Semantic Fluency Switches for Ultra-Processed Meals at 30 Minutes

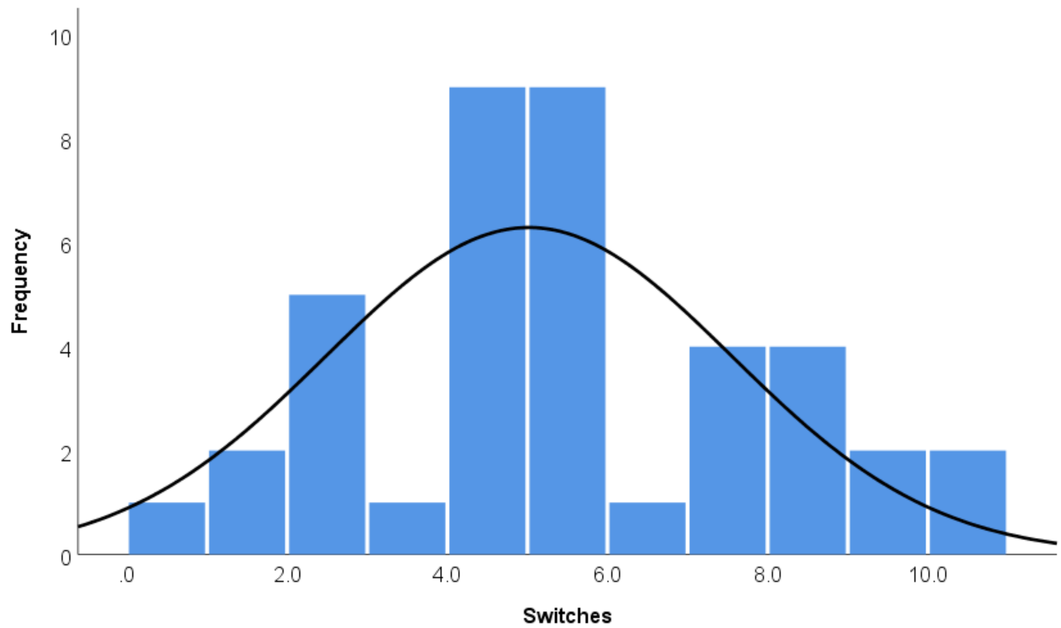


Figure E72

Histogram of Semantic Fluency Switches for Ultra-Processed Meals at 90 Minutes

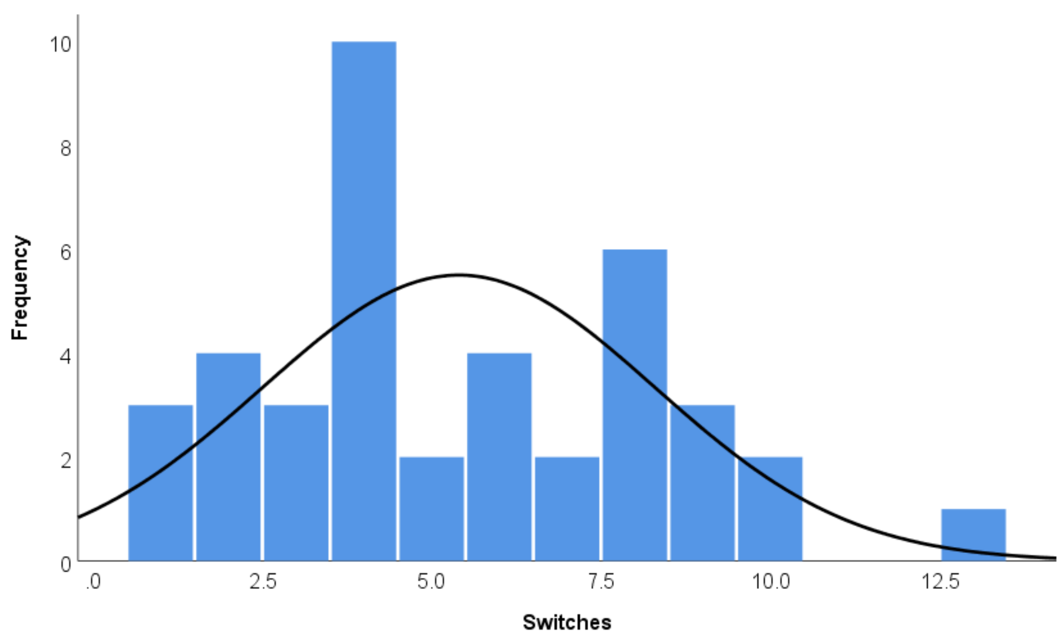


Figure E73

Histogram of Semantic Fluency Total Cluster Size for Minimally Processed Meals at 30 Minutes

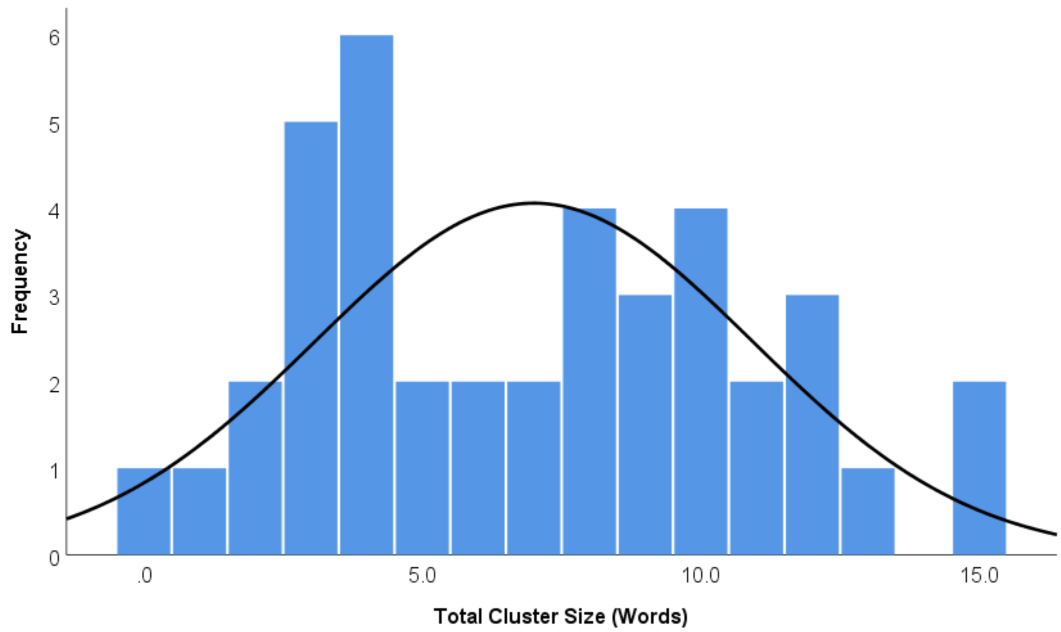


Figure E74

Histogram of Semantic Fluency Total Cluster Size for Minimally Processed Meals at 90 Minutes

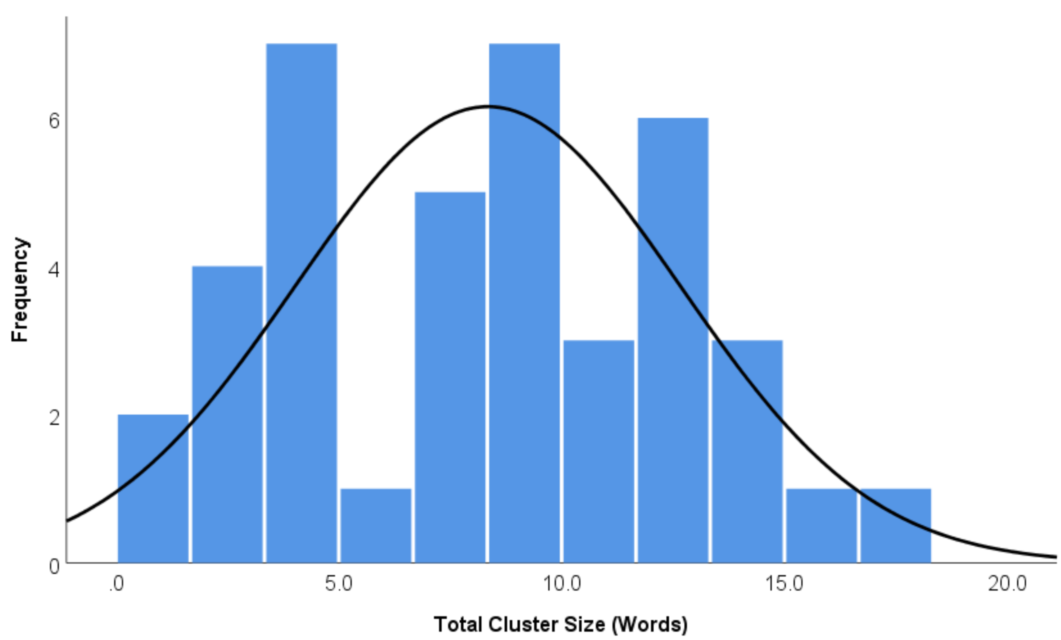


Figure E75

Histogram of Semantic Fluency Total Cluster Size for Ultra-Processed Meals at 30 Minutes

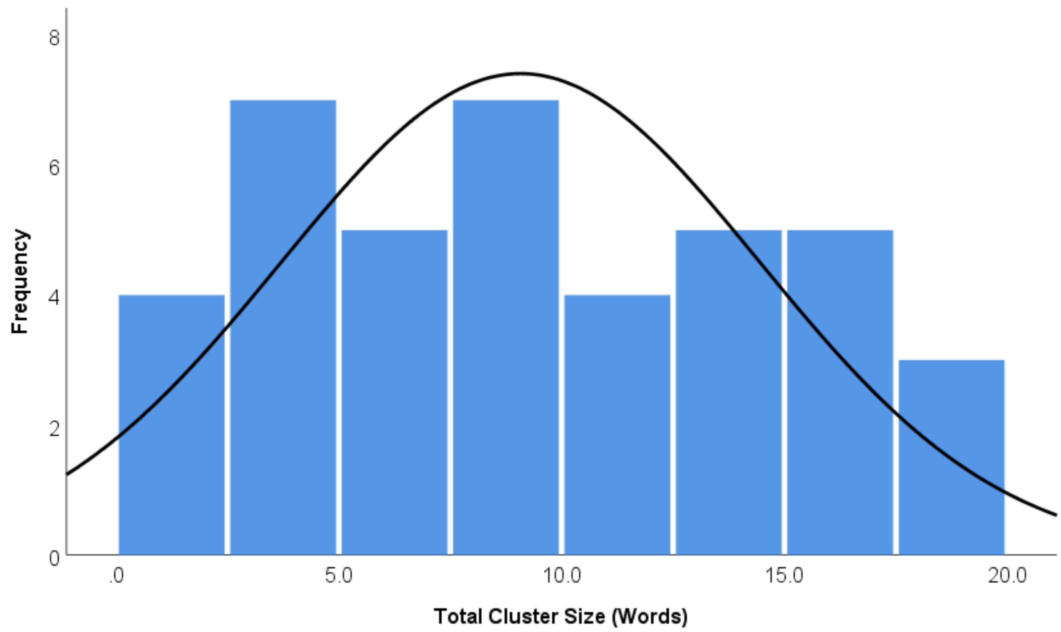


Figure E76

Histogram of Semantic Fluency Total Cluster Size for Ultra-Processed Meals at 90 Minutes

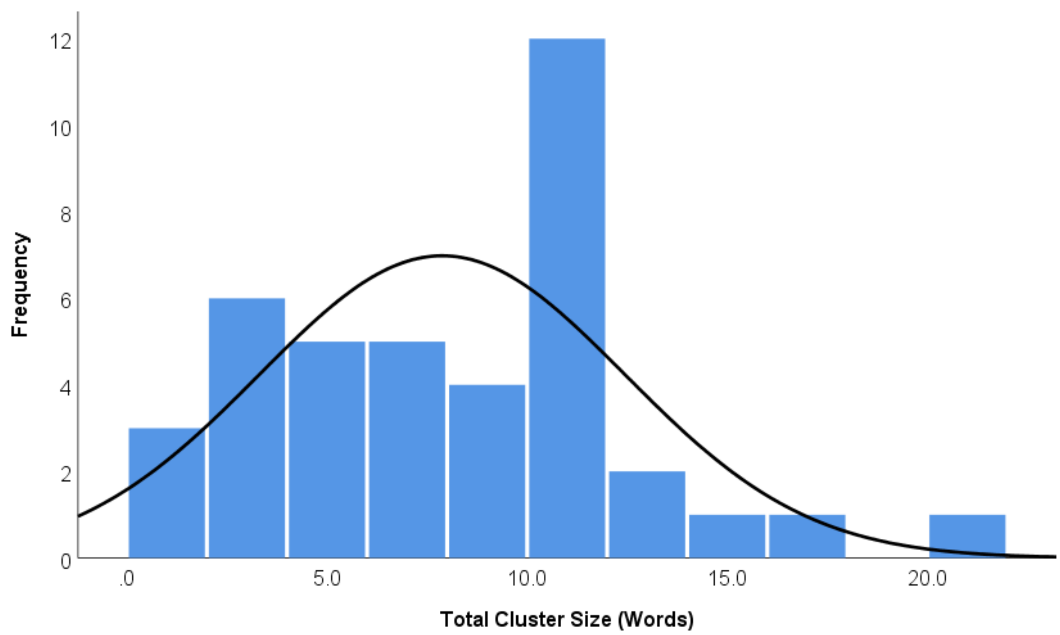


Figure E77

Histogram of Semantic Fluency Average Cluster Size for Minimally Processed Meals at 30 Minutes

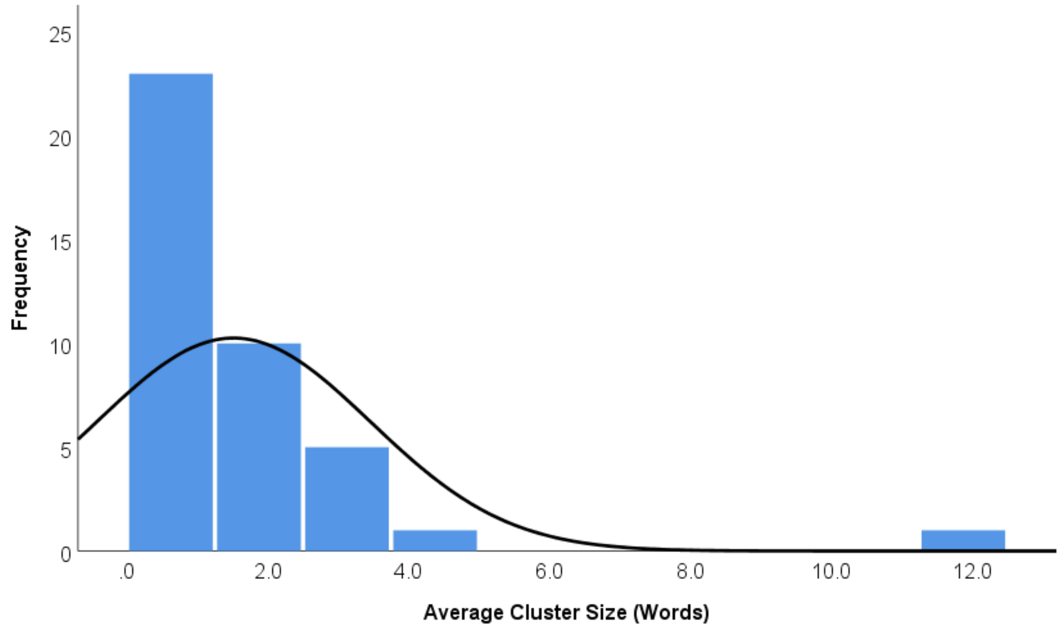


Figure E78

Histogram of Semantic Fluency Average Cluster Size for Minimally Processed Meals at 90 Minutes

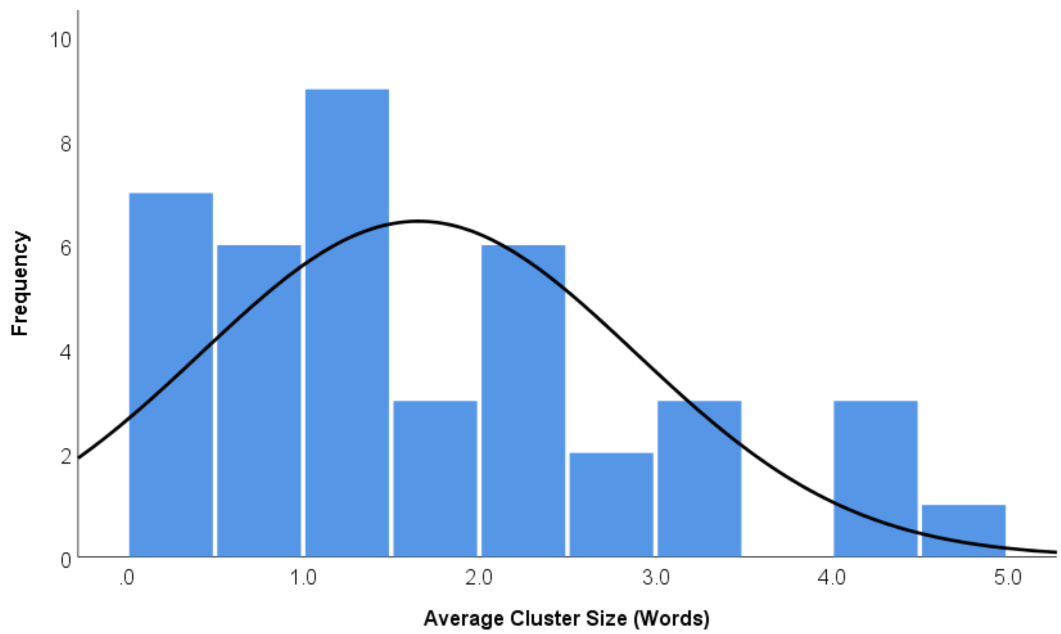


Figure E79

Histogram of Semantic Fluency Average Cluster Size for Ultra-Processed Meals at 30 Minutes

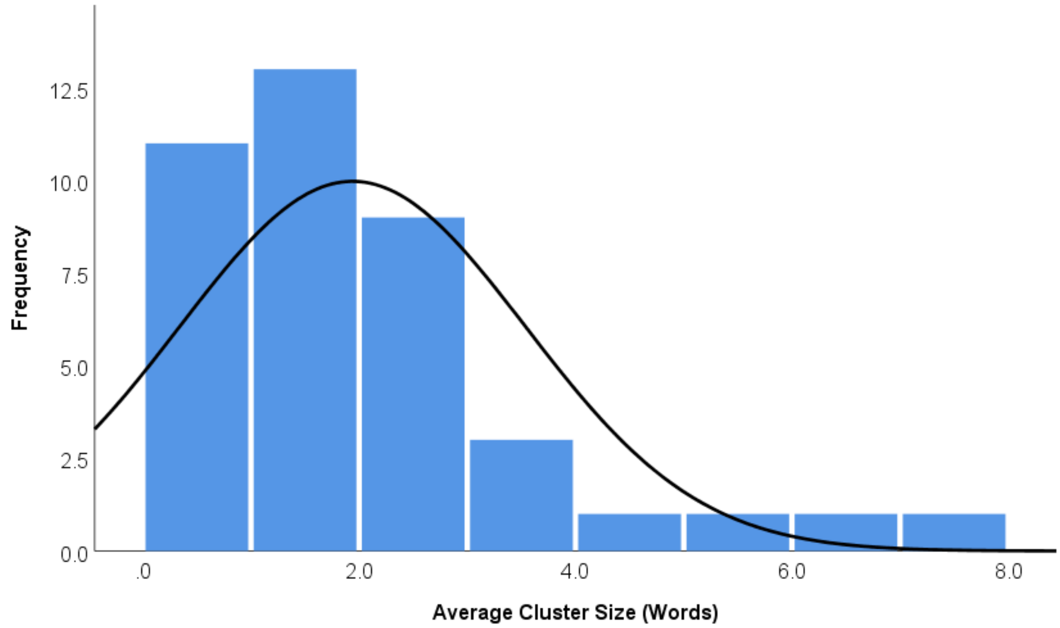
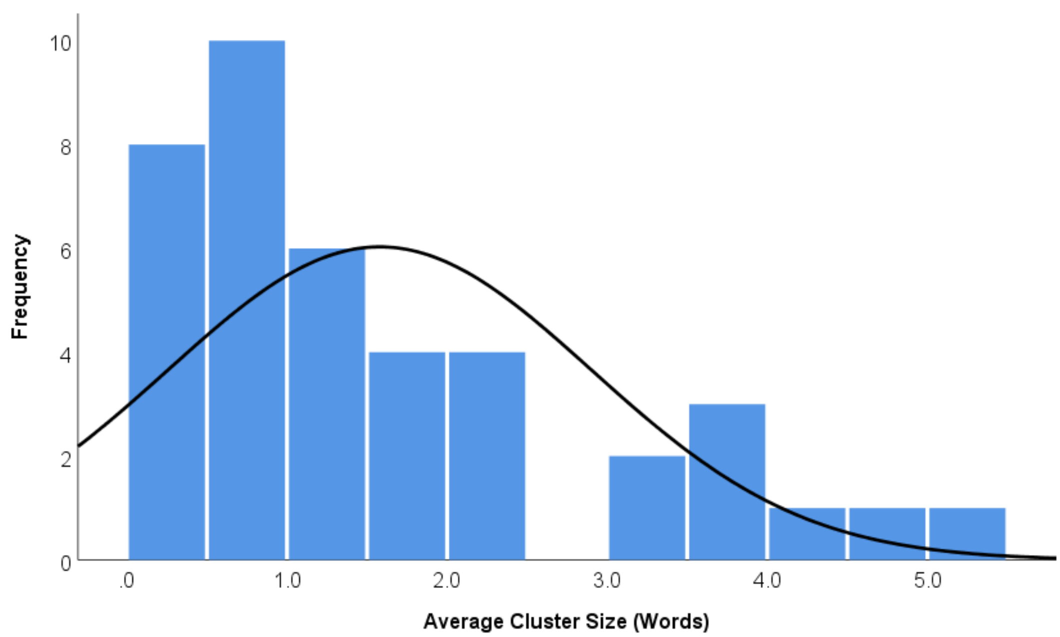


Figure E80

Histogram of Semantic Fluency Average Cluster Size for Ultra-Processed Meals at 90 Minutes



Appendix F: Additional Statistics Results

Table F1

Normality Tests for Verbal Learning Total Recall

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*p*	Statistic	*df*	*p*
Minimally Processed at 30 Minutes	.11	40	.20[b]	.97	40	.46
Minimally Processed at 90 Minutes	.13	40	.11	.97	40	.34
Ultra-Processed at 30 Minutes	.15*	40	.02	.95	40	.08
Ultra-Processed at 90 Minutes	.08	40	.20[b]	.99	40	.90

[a] Lilliefors Significance Correction
[b] This is a lower bound of the true significance.
$^{*}p < .05$. $^{**}p < .01$

Table F2

Normality Tests for Verbal Learning Immediate Memory

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*p*	Statistic	*df*	*p*
Minimally Processed at 30 Minutes	.15*	40	.03	.95	40	.06
Minimally Processed at 90 Minutes	.24**	40	<.01	.88**	40	<.01
Ultra-Processed at 30 Minutes	.17*	40	.01	.94*	40	.04
Ultra-Processed at 90 Minutes	.15*	40	.03	.95	40	.07

[a] Lilliefors Significance Correction
[b] This is a lower bound of the true significance.
$^{*}p < .05$. $^{**}p < .01$

Table F3

Normality Tests for Verbal Learning Delayed Recall

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*p*	Statistic	*df*	*p*
Minimally Processed at 30 Minutes	.18**	40	<.01	.92*	40	.01
Minimally Processed at 90 Minutes	.11	40	.20[b]	.96	40	.23
Ultra-Processed at 30 Minutes	.13	40	.07	.94*	40	.05
Ultra-Processed at 90 Minutes	.11	40	.20[b]	.95	40	.09

[a] Lilliefors Significance Correction
[b] This is a lower bound of the true significance.
$^{*}p < .05$. $^{**}p < .01$

Table F4

Normality Tests for Verbal Learning Recognition

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*p*	Statistic	*df*	*p*
Minimally Processed at 30 Minutes	.28**	40	<.01	.68**	40	<.01
Minimally Processed at 90 Minutes	.17*	40	.01	.85**	40	<.01
Ultra-Processed at 30 Minutes	.21**	40	<.01	.87**	40	<.01
Ultra-Processed at 90 Minutes	.15*	40	.02	.91**	40	<.01

[a] Lilliefors Significance Correction
[b] This is a lower bound of the true significance.
$^{*}p < .05$. $^{**}p < .01$

Table F5

Normality Tests for Verbal Learning Interference List Score

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*p*	Statistic	*df*	*p*
Minimally Processed at 30 Minutes	.20**	40	<.01	.92*	40	.01
Minimally Processed at 90 Minutes	.21**	40	<.01	.92*	40	.01
Ultra-Processed at 30 Minutes	.16*	40	.01	.94*	40	.03
Ultra-Processed at 90 Minutes	.26**	40	<.01	.77**	40	<.01

[a] Lilliefors Significance Correction
[b] This is a lower bound of the true significance.
$^{*}p < .05$. $^{**}p < .01$

Table F6

Normality Tests for Verbal Learning Retention

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*p*	Statistic	*df*	*p*
Minimally Processed at 30 Minutes	.19**	40	<.01	.92*	40	.01
Minimally Processed at 90 Minutes	.14	40	.06	.95*	40	.05
Ultra-Processed at 30 Minutes	.13	40	.11	.93*	40	.02
Ultra-Processed at 90 Minutes	.11	40	.20[b]	.93*	40	.02

[a] Lilliefors Significance Correction
[b] This is a lower bound of the true significance.
$^{*}p < .05$. $^{**}p < .01$

Table F7

Normality Tests for Verbal Learning Proactive Interference

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*p*	Statistic	*df*	*p*
Minimally Processed at 30 Minutes	.15*	40	.02	.95	40	.08
Minimally Processed at 90 Minutes	.12	40	.12	.95	40	.08
Ultra-Processed at 30 Minutes	.15*	40	.03	.97	40	.26
Ultra-Processed at 90 Minutes	.15*	40	.02	.93*	40	.02

[a] Lilliefors Significance Correction
[b] This is a lower bound of the true significance.
*p < .05. **p < .01

Table F8

Normality Tests for Verbal Learning Retroactive Interference

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*p*	Statistic	*df*	*p*
Minimally Processed at 30 Minutes	.16*	40	.01	.88**	40	<.01
Minimally Processed at 90 Minutes	.22**	40	<.01	.86**	40	<.01
Ultra-Processed at 30 Minutes	.15*	40	.02	.96	40	.14
Ultra-Processed at 90 Minutes	.19**	40	<.01	.91**	40	<.01

[a] Lilliefors Significance Correction
[b] This is a lower bound of the true significance.
*p < .05. **p < .01

Table F9

Normality Tests for Phonemic Fluency Score

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*p*	Statistic	*df*	*p*
Minimally Processed at 30 Minutes	.13	40	.12	.91**	40	<.01
Minimally Processed at 90 Minutes	.12	40	.15	.95	40	.06
Ultra-Processed at 30 Minutes	.13	40	.07	.93*	40	.02
Ultra-Processed at 90 Minutes	.14*	40	.04	.95	40	.08

[a] Lilliefors Significance Correction
[b] This is a lower bound of the true significance.
*p < .05. **p < .01

Table F10

Normality Tests for Phonemic Fluency Perseverations

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*p*	Statistic	*df*	*p*
Minimally Processed at 30 Minutes	.39**	40	<.01	.64**	40	<.01
Minimally Processed at 90 Minutes	.36**	40	<.01	.52**	40	<.01
Ultra-Processed at 30 Minutes	.39**	40	<.01	.50**	40	<.01
Ultra-Processed at 90 Minutes	.42**	40	<.01	.42**	40	<.01

[a] Lilliefors Significance Correction
[b] This is a lower bound of the true significance.
$^{*}p < .05$. $^{**}p < .01$

Table F11

Normality Tests for Phonemic Fluency Intrusions

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*p*	Statistic	*df*	*p*
Minimally Processed at 30 Minutes	.27**	40	<.01	.63**	40	<.01
Minimally Processed at 90 Minutes	.33**	40	<.01	.68**	40	<.01
Ultra-Processed at 30 Minutes	.29**	40	<.01	.78**	40	<.01
Ultra-Processed at 90 Minutes	.29**	40	<.01	.75**	40	<.01

[a] Lilliefors Significance Correction
[b] This is a lower bound of the true significance.
$^{*}p < .05$. $^{**}p < .01$

Table F12

Normality Tests for Phonemic Fluency Switches

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*p*	Statistic	*df*	*p*
Minimally Processed at 30 Minutes	.14*	40	.04	.95	40	.06
Minimally Processed at 90 Minutes	.11	40	.20[b]	.94*	40	.05
Ultra-Processed at 30 Minutes	.10	40	.20[b]	.92*	40	.01
Ultra-Processed at 90 Minutes	.17*	40	.01	.90**	40	<.01

[a] Lilliefors Significance Correction
[b] This is a lower bound of the true significance.
$^{*}p < .05$. $^{**}p < .01$

Table F13

Normality Tests for Phonemic Fluency Total Cluster Size

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*p*	Statistic	*df*	*p*
Minimally Processed at 30 Minutes	.13	40	.11	.91**	40	<.01
Minimally Processed at 90 Minutes	.22**	40	<.01	.88**	40	<.01
Ultra-Processed at 30 Minutes	.13	40	.09	.93*	40	.02
Ultra-Processed at 90 Minutes	.15*	40	.03	.86**	40	<.01

[a] Lilliefors Significance Correction
[b] This is a lower bound of the true significance.
$^{*}p < .05$. $^{**}p < .01$

Table F14

Normality Tests for Phonemic Fluency Average Cluster Size

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*p*	Statistic	*df*	*p*
Minimally Processed at 30 Minutes	.12	40	.16	.90**	40	<.01
Minimally Processed at 90 Minutes	.19**	40	<.01	.90**	40	<.01
Ultra-Processed at 30 Minutes	.18**	40	<.01	.93*	40	.01
Ultra-Processed at 90 Minutes	.10	40	.20[b]	.93*	40	.02

[a] Lilliefors Significance Correction
[b] This is a lower bound of the true significance.
$^{*}p < .05$. $^{**}p < .01$

Table F15

Normality Tests for Semantic Fluency Score

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*p*	Statistic	*df*	*p*
Minimally Processed at 30 Minutes	.18**	40	<.01	.95	40	.06
Minimally Processed at 90 Minutes	.09	40	.20[b]	.98	40	.61
Ultra-Processed at 30 Minutes	.17*	40	.01	.96	40	.15
Ultra-Processed at 90 Minutes	.08	40	.20[b]	.97	40	.44

[a] Lilliefors Significance Correction
[b] This is a lower bound of the true significance.
$^{*}p < .05$. $^{**}p < .01$

Table F16

Normality Tests for Semantic Fluency Perseverations

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*p*	Statistic	*df*	*p*
Minimally Processed at 30 Minutes	.54**	40	<.01	.15**	40	<.01
Minimally Processed at 90 Minutes	.50**	40	<.01	.30**	40	<.01
Ultra-Processed at 30 Minutes	.48**	40	<.01	.31**	40	<.01
Ultra-Processed at 90 Minutes	.53**	40	<.01	.34**	40	<.01

[a] Lilliefors Significance Correction
[b] This is a lower bound of the true significance.
$^{*}p < .05$. $^{**}p < .01$

Table F17

Normality Tests for Semantic Fluency Intrusions

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*p*	Statistic	*df*	*p*
Minimally Processed at 30 Minutes	.47**	40	<.01	.51**	40	<.01
Minimally Processed at 90 Minutes	.27**	40	<.01	.67**	40	<.01
Ultra-Processed at 30 Minutes	.37**	40	<.01	.57**	40	<.01
Ultra-Processed at 90 Minutes	.43**	40	<.01	.61**	40	<.01

[a] Lilliefors Significance Correction
[b] This is a lower bound of the true significance.
$^{*}p < .05$. $^{**}p < .01$

Table F18

Normality Tests for Semantic Fluency Switches

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*p*	Statistic	*df*	*p*
Minimally Processed at 30 Minutes	.14*	40	.04	.97	40	.32
Minimally Processed at 90 Minutes	.10	40	.20[b]	.98	40	.54
Ultra-Processed at 30 Minutes	.15*	40	.02	.96	40	.20
Ultra-Processed at 90 Minutes	.19**	40	<.01	.95	40	.07

[a] Lilliefors Significance Correction
[b] This is a lower bound of the true significance.
$^{*}p < .05$. $^{**}p < .01$

Table F19

Normality Tests for Semantic Fluency Total Cluster Size

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*p*	Statistic	*df*	*p*
Minimally Processed at 30 Minutes	.15*	40	.02	.96	40	.17
Minimally Processed at 90 Minutes	.12	40	.18	.97	40	.26
Ultra-Processed at 30 Minutes	.13	40	.11	.95	40	.10
Ultra-Processed at 90 Minutes	.13	40	.10	.94*	40	.04

[a] Lilliefors Significance Correction
[b] This is a lower bound of the true significance.
$^{*}p < .05$. $^{**}p < .01$

Table F20

Normality Tests for Semantic Fluency Average Cluster Size

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	*df*	*p*	Statistic	*df*	*p*
Minimally Processed at 30 Minutes	.23**	40	<.01	.57**	40	<.01
Minimally Processed at 90 Minutes	.18**	40	<.01	.91**	40	<.01
Ultra-Processed at 30 Minutes	.14*	40	.05	.87**	40	<.01
Ultra-Processed at 90 Minutes	.18**	40	<.01	.86**	40	<.01

[a] Lilliefors Significance Correction
[b] This is a lower bound of the true significance.
$^{*}p < .05$. $^{**}p < .01$